MAR [illegible]

INSTRUMENTS

THE MAGAZINE OF MEASUREMENT AND CONTROL

VOLUME 6 MARCH, 1933 NUMBER 3

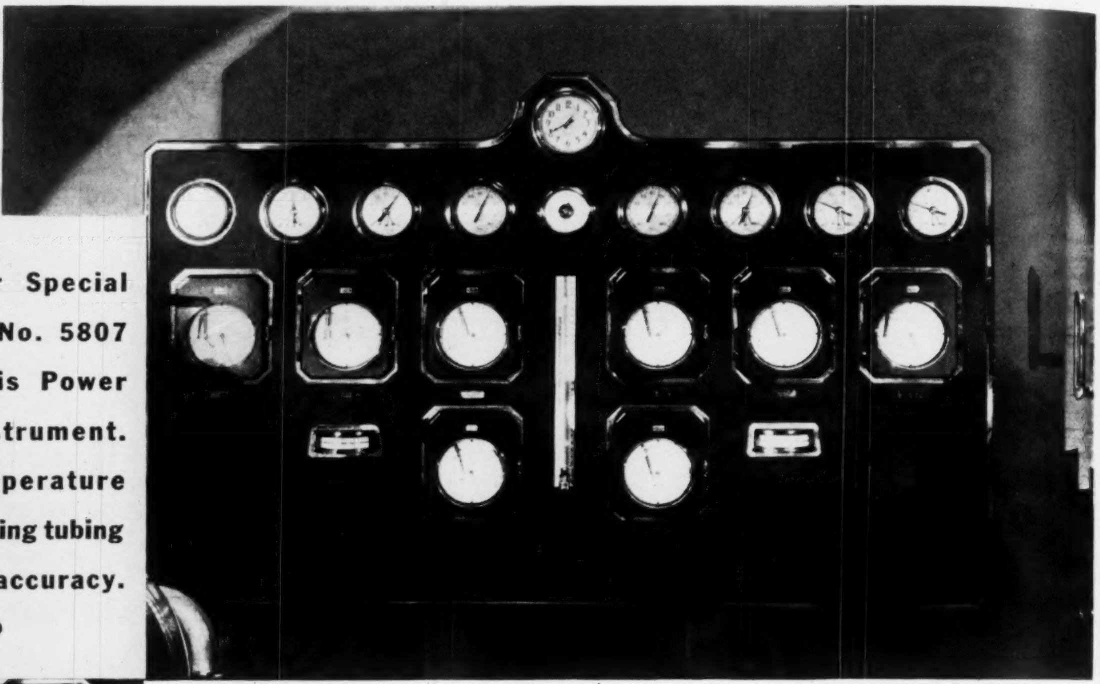
MICROSCOPE "FEATURED" IN THE RECENT R. K. O. RELEASE "SECRETS OF THE FRENCH POLICE" (*Courtesy Bausch & Lomb Optical Co.*)

TEMPERATURE and HUMIDITY MEASUREMENT and CONTROL
[illegible] PAGES [illegible] ILLUSTRATIONS [illegible] POSTPAID INSTRUMENTS PUBLISHING CO.

NEW

Beauty, Accuracy, Reliability

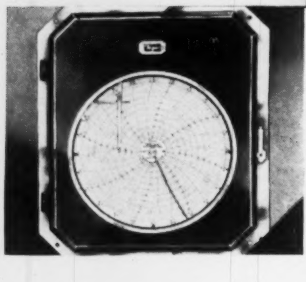
WITH THIS NEW TAYLOR RECORDER



Send for Special Bulletin No. 5807 about this Power Plant Instrument. New temperature compensating tubing assures accuracy.

●

Modern power plant panel board showing use of new Taylor Rectangular Recorder



BEAUTY in power plant recorders? Here it is in the new Taylor Rectangular Recorder. And with it even greater accuracy and ruggedness than you have experienced in past Taylor instruments.

You can get it in a smooth, lustrous, all-black case or a black case with polished aluminum flange. There's one design for surface and another for flush mounting.

Accuracy is assured by special mechanical features in the recorder and by an exclusive Taylor product, Accuratus Tubing, which automatically compensates for fluctuating temperatures between bulb and recorder.

Now note the following features: simplified movement with minimum friction; stainless steel pen and arm; micrometer pen adjustment; time target for setting time on time line; extra-strong hinges; positive locking door latch; heat-treated and aged alloy springs; one-, two-, or three-pen types; spring wound or electric clock.

Mercury-, vapor-, and gas-actuated types are available. The mercury-actuated recorder is especially recommended for power plants, and is particularly valuable in taking the temperatures of superheated steam. With mercury-filling and the remarkable Accuratus Tubing, open range charts can be used with graduations from 650° to 800°F. in 2° divisions.

Send for our Special Bulletin No. 5807, which describes in greater detail the superiority of this new Power Plant Recorder and Accuratus Tubing. Taylor Instrument Companies, Rochester, N. Y.

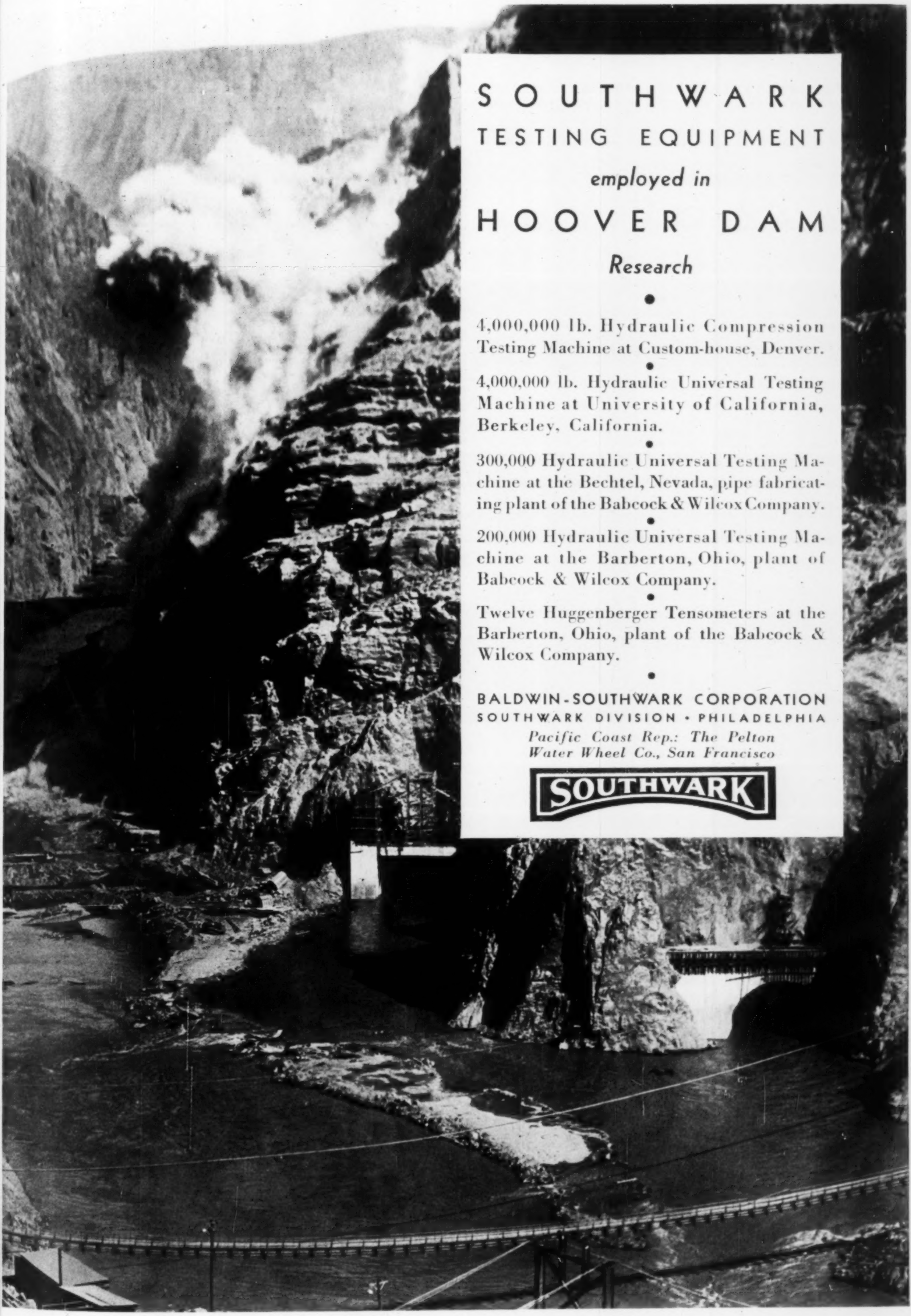
ASSURING ACCURACY WITH ACCURATUS TUBING

When you use Accuratus Tubing with the new mercury-actuated Power Plant Recorder, the chart record shows only one temperature—the temperature at the bulb. This is true whether tube lengths are 100 feet or more. The tubing automatically compensates for fluctuating temperatures along its entire length. Nearby steam coils or brine pipes have no effect on the true temperature at the bulb. Temperature compensation is permanent. It is built into the tubing.

*Tycos Taylor **TEMPERATURE *and* PRESSURE INSTRUMENTS**

*The name Taylor now identifies our complete line of products including Tycos instruments.

INDICATING · RECORDING · CONTROLLING



SOUTHWARK TESTING EQUIPMENT

employed in

HOOVER DAM

Research

●

4,000,000 lb. Hydraulic Compression Testing Machine at Custom-house, Denver.

●

4,000,000 lb. Hydraulic Universal Testing Machine at University of California, Berkeley, California.

●

300,000 Hydraulic Universal Testing Machine at the Bechtel, Nevada, pipe fabricating plant of the Babcock & Wilcox Company.

●

200,000 Hydraulic Universal Testing Machine at the Barberton, Ohio, plant of Babcock & Wilcox Company.

●

Twelve Huggenberger Tensometers at the Barberton, Ohio, plant of the Babcock & Wilcox Company.

●

BALDWIN-SOUTHWARK CORPORATION
SOUTHWARK DIVISION • PHILADELPHIA
Pacific Coast Rep.: The Pelton Water Wheel Co., San Francisco

SOUTHWARK

INSTRUMENTS

THE MAGAZINE of MEASUREMENT and CONTROL

RICHARD RIMBACH
Managing Editor

Engineering Editor
M. F. BEHAR

Editorial Advisory Board
G. BERNDT
Technische Hochschule, Dresden, Germany
W. G. BROMBACHER
United States Bureau of Standards
A. V. De FOREST
American Chain Company
K. J. DeJUHASZ
Pennsylvania State College
PAUL B. FINDLEY
Bell Telephone Laboratories
JOHN L. HAUGHTON
National Physical Laboratory, England
H. L. HAZELTINE
Sterling Varnish Company
C. A. HEILAND
Colorado School of Mines
HANS VON JUEPTNER
University of Vienna, Austria
GEORGE KEINATH
Editor, Archiv fuer Technisches Messen
FRIEDRICH KOERBER
Kaiser-Wilhelm-Institut fuer Eisenforschung, Germany
E. S. LINCOLN
Consulting Electrical Engineer
RICHARD R. MOORE
Wright Aeronautical Corporation
ALLEN LESLIE NORBURY
British Cast Iron Research Association
FOSTER D. SNELL
Consulting Chemist
THOMAS SPOONER
Westinghouse Electric and Manufacturing Company
FRANCIS M. TURNER
Chemical Catalog Company
JOSEPH LYNCH, S. J.
Seismic Station, Fordham University
S. R. WILLIAMS
Amherst College
W. R. WORK
Carnegie Institute of Technology

◆

Advertising Offices:
Main Office, 3619 Forbes St., Pittsburgh.
Boston, 6 Marlborough Street.
Chicago, Room 865, Daily News Bldg.
New York, 330 West 42 St.

◆

Published Monthly on the 15th by
The Instruments Publishing Company
3619 Forbes Street, Pittsburgh, Pa.
JOSEPH J. VIGNEAU, President
RICHARD RIMBACH, Vice-Pres.-Treas.

◆

Annual Subscription: U. S. $2.00. All other countries $5.00. (Remit by New York Draft to 3619 Forbes St., Pittsburgh, Pa.) Copyright 1933 by The Instruments Publishing Company. Entered as second-class matter January 26, 1932, at the post office at Pittsburgh, Pa., under the Act of March 3, 1879.

CONTENTS · MARCH, 1933

Cover: Microscope "Starred" in a Film Scene

Control of Fractional Horse-Power Motors 46
F. L. Spangler

The Engine Indicator—Its Theory and Design . . . 47
Kalman J. DeJuhasz

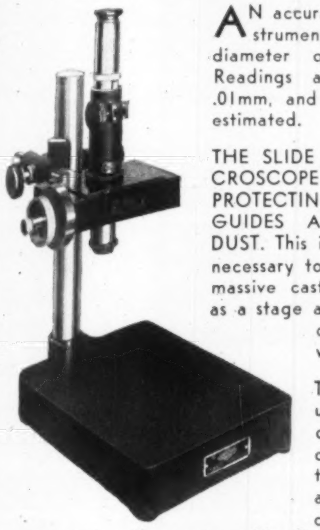
Fluid Flow Control 53
M. F. Behar and Ed S. Smith, Jr.

Editorial Comment 45
Instruments Abstracts A5
Instruments Index A6
Advertisers' Index A8
Manufacturers' Literature 54

New Instruments

Square Case Instruments 56
Vacuum Contact Relays 56
Small Split-phase Motors 57
Photoelectric Controller 57
Potentiometer Stabilog 58
Rotary Snap Switch 58
Dial Thermometers and Pressure Gages 59
Improved Instrument Fuses 59
Small Circular Slide Rule 60
Midget "Megger" Tester 60
Small Universal Measuring Machine 61
Tension Indicators 61
New Circuits for Controls 62
Cambridge Pot Galvanometer 62
Automatic Cement Batchers 62
New Model Potentiometers 63
Solution Feed Equipment 63
Apparatus and Instrument Supports 63
Differential Pressure Indicator 64
Automatic System Supplies Proper Air Weight 64
Cold Bend Testing Machine 64
Bailey Escapement Integrator 65
Four-dial Resistance Box 65
An Electric Taster 65
New Electric Metering Unit 65
Re-designed Round-chart Recorder 66
Magnetrole Relay 66
Portable Electrical Instruments 66
Pilot-controlled, Self powered Water Regulating Valve 66
Pyrometer Controller Employs New Principle 67
Mercury Swing Type Relay 67
New Design Rheostat 67

BRINELL MICROSCOPE



An accurate and dependable instrument for measuring the diameter of Brinell impressions. Readings are made directly to .01mm, and .001mm is very easily estimated.

THE SLIDE CARRYING THE MICROSCOPE IS FULLY ENCLOSED, PROTECTING THE SCREW AND GUIDES AGAINST DIRT AND DUST. This is an important feature necessary to a shop instrument. A massive cast-iron base serves also as a stage accommodating samples of considerable size and weight.

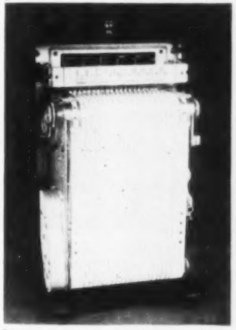
This instrument can be used continuously without causing eye-strain or any discomfort to the operator. It may also be used for vertical measurements and inspection of surfaces not readily placed on the stage.

For detailed description we refer to our Catalog M-130 copies of which will be sent on request.

THE GAERTNER SCIENTIFIC CORP.
1201 Wrightwood Ave. Chicago, U. S. A.

---

20 Records
ON ONE CHART



Meter with Cover Off

●

Here is an instrument that will record idle time on 20 machines.

It is largely used in industry for recording the time on processing, production time, etc.

●

Bulletins 330, 529 and 831 describing these instruments and their uses will be sent free on request.

THE ESTERLINE-ANGUS CO.
INDIANAPOLIS, IND., U. S. A.

NEW . . .

Heavy-Current Rheostats

For all kinds of heavy-duty service, the new General Radio Type 333 and Type 533 Rheostats are well adapted. They are ruggedly built and conservatively rated.

FEATURES

1. Power ratings of 100 watts and 250 watts
2. Rotary control
3. Small steps, wire-to-wire
4. Resistances of 1, 3, 10, 30, 100, 300, and 600 ohms

Prices: $4.00 and $6.00

Write for complete specifications. Ask for Bulletin Ex-3302 and address

GENERAL RADIO COMPANY
CAMBRIDGE, MASSACHUSETTS

"pH" *Greater Utility and Convenience.. ..by using the new* HELLIGE *DIRECT READING*

pH Potentiometers

NEW NEW

1 pH = 58,1 mV
H INC.

DISCUS MODE NUMBER 7010

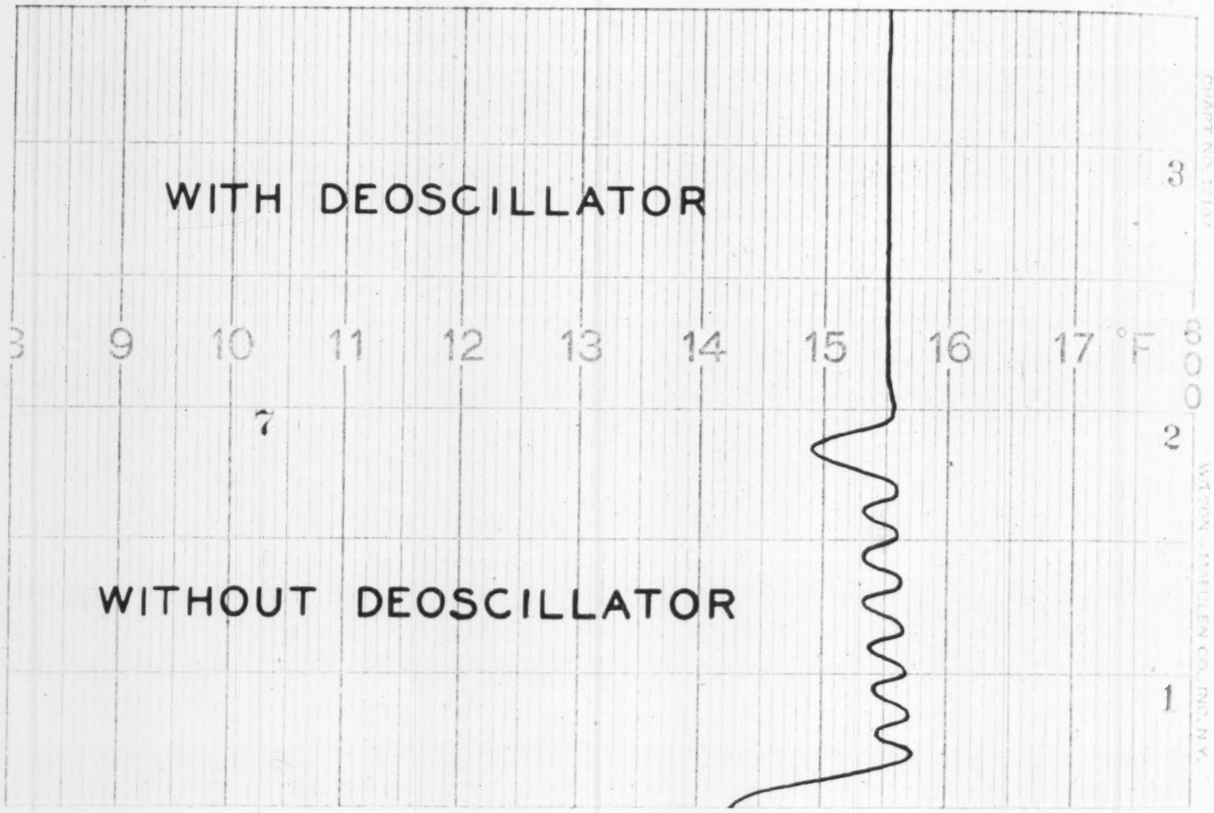
WRITE FOR BULLETIN 7000

HELLIGE

179 EAST 87TH STREET, NEW YORK, N.Y.

Add The DEOSCILLATOR . . .

FOR SMOOTH, CLOSE CONTROL WITH YOUR PRESENT PYROMETER CONTROLLER



An Inexpensive Method of Improving Operation of **Any** Pyrometer Controller.

The Deoscillator positively eliminates hunting and over-controlling. It gives anticipating action to any make of pyrometer controller. It is rugged, inexpensive, easy to install and applicable to either new installations or those already in service. Write for P. D. No. 186.

FOXBORO
REG. U. S. PAT. OFF.
THE COMPASS OF INDUSTRY

THE FOXBORO COMPANY
FOXBORO, MASS., U. S. A.
BRANCH OFFICES IN ALL PRINCIPAL CITIES

. . . Complete Industrial Instrumentation . . .

EDITORIAL COMMENT

In This Issue

◆ It has been said that whereas "an indicator or a recorder merely reports conditions as would a subordinate sent to look over a situation, a controller takes action as would an alert executive to whom reports are submitted." But an executive must have reliable subordinates to make his "action" effective. Hence the importance of devices for the **Control of Small Motors. F. L. Spangler** knows this subject—and so will our readers when they get through with his articles, of which the first appears this month.

◆ **Professor DeJuhasz** starts a chapter on cyclic indicators in this month's instalment of his book on **The Engine Indicator.** These are modern instruments, and our readers will find the article intensely interesting and stimulating.

◆ The "control" part of **Béhar's** book on flow measurement and control turns out to be a collaboration. The co-author is **Ed S. Smith, Jr.,** whose long practical experience in this field qualifies him eminently to evaluate various **Fluid Rate Control Systems** as he does in this month's issue.

◆ Equalling the previous record, the **New Instruments** section contains thirty-three descriptive articles, nearly all of them illustrated. We estimate the reading-time of these 26 columns as 52 minutes—and what a profitable hour is in store for you!

◆ Of the other departments and regular features, the **Manufacturers' Literature** has seldom been featured in this column. We now hasten to remedy this omission and to point out that every plant and laboratory will find it advantageous to send—every month—for some of the booklets and catalogues describing improved products.

◆ ◆ ◆

The Front Cover

◆ No, this conservative technical journal hasn't "gone Hollywood" but it has gone *to* Hollywood *via* the Bausch & Lomb Optical Co. for a cover illustration which is not only dramatic in itself (trust R.K.O. for that!) but of practical interest as suggestive of the wide variety of special microscope equipment on the market. Crime detection is but one of the many technical fields served by the modern descendants of Galileo and Van Leeuwenhoek.

"The Breaks"...and You

FROM such statistics as are available it appears that never before in all the history of American industries has the turnover of engineers and operating executives reached such appalling proportions. So much so that if the preceding sentence were read by the "average" technical man, he would say to himself, "I know this to be true for I myself am one of the statistical cases."

In normal times, few mature engineers, research men, laboratory workers or superintendents changed jobs during any given year; now, the majority are not doing today what they were doing a year ago; many have undergone a change of status since the first of January.

No observer need consult statistics to be struck by the sad fact that most of the changes of status have been for the worse. Many now ride to work who drove to work a few months ago. Many scan the want ads today who scanned their assistants' reports yesterday.

The impression now prevails that this process will henceforth reverse itself. International economic conferences are being called; the "New Deal" is at work; great engineering projects will be launched; car-loadings, bank clearings and other indices will go up; in short, as the great ones proclaim, the depression is definitely over.

"Consequently," rejoices the individual technical man, "consequently *my* outlook is brighter; consequently *I* personally must benefit; consequently *my* salary *will* be raised, or 'they' will offer *me* a better job." (or, "I shall certainly be offered a job.")

Such reasoning, it seems to us, is faulty. It isn't even reasoning: it is day-dreaming. We would not blurt it out to an ordinary audience—say to the crowd at a ball game—but addressing measurement-minded men as we do here, we believe that we can render a distinct service by cautioning our readers against disregarding statistical laws that hold as true today as they did in normal times.

The owner of a strategically located department store is justified in feeling certain that returning prosperity will augment *his* sales; of a railroad, that *he* will carry more passengers and freight; of securities, that *his* dividends will be higher. These certainties are founded on laws of probability similar to those that make the work of an insurance actuary a mathematical task rather than a gamble. (Even in the case of the securities holder, if his portfolio is not diversified, he is more or less of a gambler.)

Few individual workers whose security depends on their personal abilities, however, have any valid reasons for such mathematical certainty as to their own futures.

True it is that better days are in store for our professions; true it is that most of us will work fewer hours for more pay—but the world has never owed even a bare living to every individual one of us slide-rule users.

What is the answer? You know it: *Personal preparedness.* For out of all the welter of kaleidoscopic changes of technical personnel there emerges, right next to the statistical fact of demotions for the "average," the more significant fact that *promotions* came to many men who "know what it's all about"—or in equally popular parlance, who "know what's what,"—to the alert men who keep up their market value by keeping up their self-improvement—keeping up, for instance, their intimate acquaintance with modern methods and new developments.

P.S. Our readers may find pleasure in one statistical datum: they constitute a group which—as appears from the small number of recent changes in our subscribers' list as compared to those of trade and technical journals in general—is exceptionally stable, remarkably secure, unusually "certain" of better days. After all, those who specialize in the measurement and control of physical variables should best be able to control some factors affecting their own status!—M. F. BEHAR

Control of Fractional-Horsepower Motors

By F. L. SPANGLER*

FRACTIONAL-HORSEPOWER motors in use today far outnumber all others. They are found throughout industry, in homes, schools, hospitals and virtually every establishment wired for electric light and power. They are directly operated by all manner of people—young as well as old. They run under every conceivable condition of service, and their duty cycles are as varied as the machines they drive.

Where speed regulation is not required, the control of fractional-horsepower motors is generally thought of as only a simple matter of switching, like turning lights on and off. In many cases, however, this does not suffice, and resistors must be used or a magnetic switch added, perhaps with overload relays that can be reset without replacements; or resistors may be used combined with starting (or accelerating) and running switches controlled by push buttons or by switches actuated by a float or by a pressure head. The proper correlation of machine, motor, and control is necessary for reliability and high efficiency, and requires an understanding of some of the principles underlying the design and application of electric control as much as a knowledge of mechanisms.

Originally the purpose of motor control was to provide means for starting, stopping, and reversing, and for speed control, if desired. With the arrival of mass production and the almost universal application of motors to small tools and appliances, the field embraced by the term "electric control" was extended to include protection against overloads and against hazards resulting from a temporary drop or interruption of line voltage.

Starting and Stopping Small Motors

Our first consideration will be the starting and stopping of fractional-horsepower motors, and speed regulation will be taken up later. The simplest method of starting a motor is to connect it directly to the supply line without the use of resistors. This method, known as across-the-line starting, is applicable where the starting current is not excessive and its duration is short enough that the windings are not apt to overheat while the motor is coming up to speed. Such conditions are met with in motors of the commutator type, both a.c. and d.c., having loads of low inertia, such as refrigeration machines, hoists, machine tools, plunger pumps, etc., which can be brought up to speed in perhaps 4 or 5 seconds.

The starting currents of single-phase motors with split-phase starting windings are often 5 or 6 times the normal full-load running current. Yet these motors must be started across-the-line in order that the starting torque will be sufficient to carry the load. Hence, motors with split-phase windings are limited to very small ratings, seldom being made larger than 1/6 h.p., so serious current surges will not occur at starting.

Polyphase a.c. motors in fractional-horsepower ratings are usually started across-the-line, even when driving fans and other types of flywheel loads.

Switches for across-the-line starting of motors may be closed and opened by hand, foot, rope, or shipper rod; by a change in water level, pressure head, or temperature; or by means of a magnet and armature. For many installations of fractional-horsepower motors, a single-pole switch will suffice for d.c. and single-phase a.c. motors and a 2-pole switch for polyphase a.c. motors. As a measure of safety, however, switches are generally provided with as many poles as there are motor leads so each lead is open when the switch is "off" and no part of the motor winding is alive.

Switches with a quick-make and quick-break mechanism are preferred for the control of motors, since a quick separation of the contacts results in rapidly extinguishing the arc and the arc is not drawn out as it is apt to be when the ordinary type of knife switch is used. Maintenance has further been reduced by providing double-break contacts to increase the arc-rupturing capacity of the switch, and by making the contacts of silver. Copper oxide, which forms on copper contacts, is a poor electrical conductor, but silver oxide is a good conductor. Hence, the heating at the surface of the contact where the motor current passes through is less with silver contacts than with copper, and welding together of the contacts is virtually eliminated by silver coating, even in the case of extremely high current densities.

The arc-rupturing capacity of the switch can be further increased by means of blowout coils and arc shields. While these features are not ordinarily required on switches used for fractional-horsepower a.c. motors, they may be required for d.c. installations. The blow-out coils rupture the arc quickly by blowing the arc stream away from the contacts, and the arc shields confine the arc and prevent flashovers between adjacent poles. The tendency of contacts to pit and to fuse together is decreased materially.

Manual Across-the-Line Switching

Small motor-driven tools and appliances for the shop and the home are generally started and stopped by manually operated switches of several different types, such as knife switches, snap switches, drum switches, clapper type switches, etc. Some of these switches are available in various styles. The snap switch, for example, may be operated by turning a knob, or by buttons, or it may be of the tumbler type. The push buttons can be replaced by various types of levers for operation by the hand, foot, rope, shipper rod, etc. The type and style of switch to be used in any specific installation will depend upon local code requirements, rating of the motor, appearance of the switch, its cost, the kind of service for which it is to be used, its location with respect to the operator or to the machine it is to control, whether no-voltage protection is to be provided as an inherent part of the switch, the personal likes and dislikes of those responsible for purchasing this switch, and other factors.

One of the simplest types of switch for controlling fractional-horsepower motors is the snap switch, one of which, combined with an overload breaker, is shown in Fig. 1. Another switch that has a large field of application is a clapper-type switch combined with overload relays which give reliable protection to the motor against damage due to overloads. These relays open the motor circuit if an overload is sustained but do not disconnect the motor where the overload is of short duration, as during acceleration from standstill. A hand-operated clapper-type switch with overload protection for a.c. motors is shown in Fig. 2. The feature of this switch is that in the case of an overload, the switch automatically opens and disconnects the motor from the line. In both switches, the overload breaker or overload relay can be reset without opening the cover of the switch box.

The normal reversing of fractional-horsepower motors is discussed elsewhere in this article.

Automatic Control of Pressure, Liquid Level, and Temperature

Fractional-horsepower motors driving pumps, compressors, fans, flue dampers, or oil burners may be started and stopped directly by a change in water level, pressure head, or temperature by employing float switches, pressure switches, thermostats, and other automatic devices, without the use of other switches or starting resistors, provided the starting current

(Continued on Page 52)

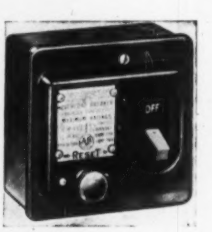


Fig. 1. Tumbler type of snap switch with overload breaker in the same box, for manual starting and stopping of small d.c. and single-phase a.c. motors.

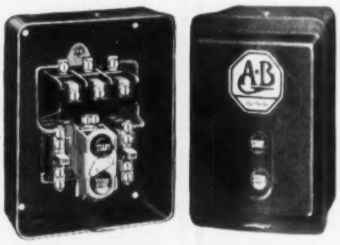


Fig. 2. Open and closed views of hand-operated 3-pole a.c. clapper-type switch. Overload relays on each side of the push button mechanism open the switch in case of overload. Pushing in the "Start" button closes the switch and starts the motor, and pushing in the "Stop" button opens the switch or resets the overload relays if they are tripped.

---

*Industrial Engineer, Allen-Bradley Co.

The ENGINE INDICATOR

By KALMAN J. DeJUHASZ*

Its Design and Theory

(Continued from February Issue)

CYCLIC PRESSURE INDICATORS

While with the previously described indicators a complete diagram is drawn during one engine cycle, there is another group of instruments in which a complete diagram is built up, point-by-point, from a large number of cycles. This procedure can be applied only if the successive cycles are sufficiently alike during the taking of the diagram, i.e. if the differences between the cycles are negligible for the purposes of investigation. This condition can be usually fulfilled in the case of high-speed engines under constant load and speed conditions. For the investigation of transient phenomena, such as for the study of one single explosion, or of the variation in the engine cycle under rapidly changing conditions, this method is not applicable. If, however, for the duration of taking a diagram a sufficient constancy of the engine cycle can be assured, then this method offers a far greater convenience and accuracy than any of the single cycle indicators. A further advantage of this method is that the resulting diagram represents mean values, which, for many engineering purposes, are preferable to the record of one single cycle.

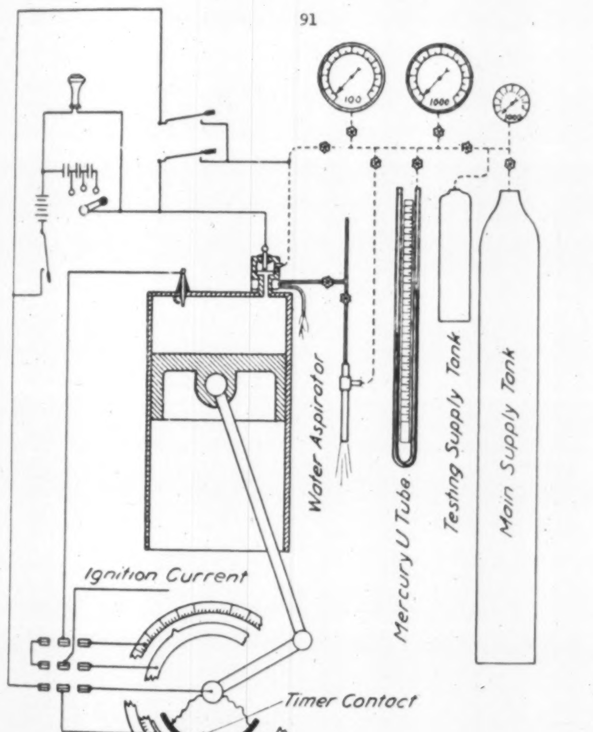


Fig. 91. Balanced Diaphragm Indicator of the Bureau of Standards (American Instrument Co.).

Indicators in this class draw the diagram either:

1. From pressure to pressure, i.e. *that* phase of the engine cycle is determined at which a given pressure exists; or
2. From phase to phase, i.e. *that* pressure is determined which exists at a given phase of the cycle.

Into Group 1 belongs the balanced diaphragm indicator developed at the Bureau of Standards and manufactured by the American Instrument Co.[15] Its principles of operation are, (a) the balancing of the cylinder pressure against a measured gas pressure on opposite sides of a metallic diaphragm of negligible stiffness, and, (b) the finding, by means of a timing device, of the engine phase at which equality of pressure occurs.

The pressure balancing element (Fig. 91a) is a thin metallic diaphragm which divides a chamber into two

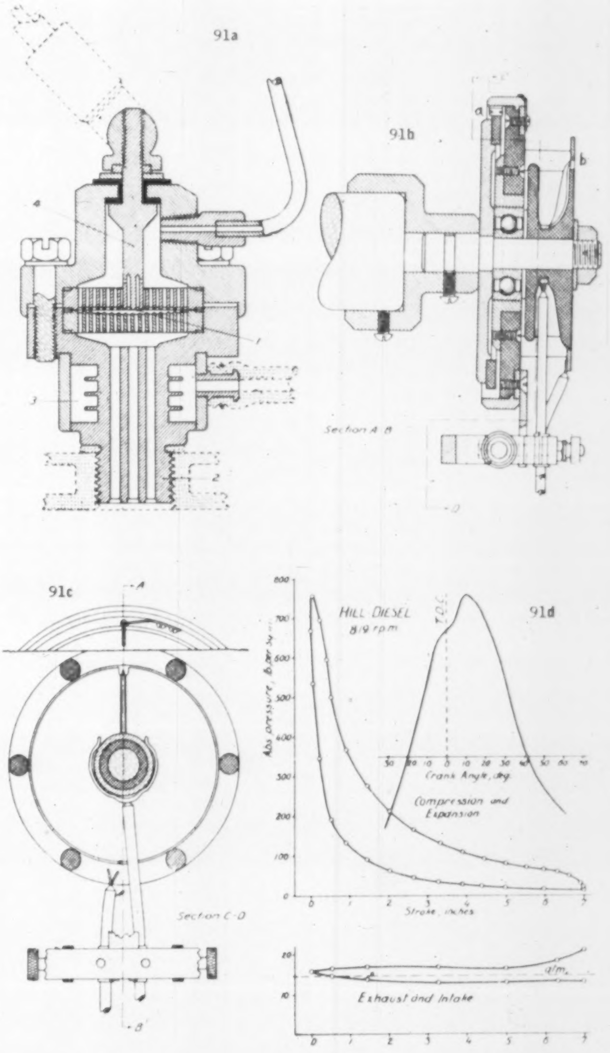


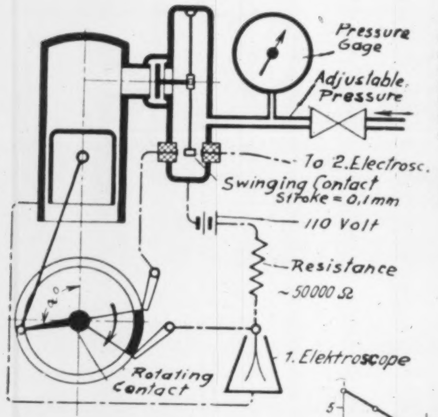
Fig. 91a shows the diaphragm assembly with water cooled connecting tube, perforated disks limiting the displacement of the diaphragm, connecting tube for the balancing pressure and the electrode. Fig. 91b and c show the timer in section and front view. On this there are two contact pairs *a* and *b* serving 2 circuits: one for the phase of the balancing pressure (*a*), and the other for finding the angle of ignition (*b*).

Fig. 91d. Diagram (pressure-stroke, pressure-crank angle) plotted from readings taken on a Hill-Diesel engine (Pennsylvania State College).

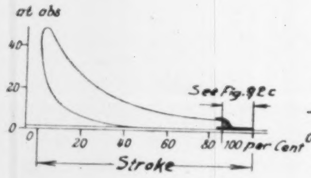
---

*Asst. Prof. of Engineering Research, Pennsylvania State College.

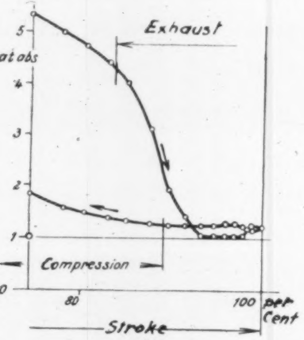
[15] H. C. Dickinson & F. B. Newell. A High Speed Engine Pressure Indicator of the Balanced Diaphragm Type., *National Advisory Committee for Aeronautics, Technical Report* No. 107, 15 pages.



92a



92b



92c

Fig. 92a. Balanced pressure indicator developed by Gasterstaedt in the Junkers Research Laboratories. (Only one of the two electroscopes is shown.) Fig. 92c is a diagram plotted from the numerical results obtained.

Fig. 92b shows the full diagram with imperfect indication of the scavenging operation.

compartments, the lower one communicating directly with the engine cylinder through a short, water-cooled passage. In the upper compartment of the chamber any predetermined pressure can be produced by means of a high pressure air (or gas) supply, a vacuum pump and suitably placed valves. Whenever the pressure in the engine cycle passes above, or below, this predetermined pressure, the diaphragm is deflected against one or the other of its limiting supports. Owing to the short natural period of the diaphragm and to its minute deflection (0.005 in.) its time lag, with which it follows the pressure change, is negligible. The phase of the cycle, at which the pressures are balanced, is determined electrically. The chamber body is insulated from the center part of the upper support which forms an electrode and is connected in series with a telephone, with a timing device and with one pole of a battery, the other pole of which is grounded to the engine and thereby to the diaphragm. The timing device (Figs. 91 b and c) is essentially an insulating disk carrying on its periphery a thin strip of conducting material. It is fastened rigidly to some part of the engine revolving at camshaft or crankshaft speed. A movable conducting brush bears against the periphery of the disk and effects a closure of the circuit for the duration of one degree of arc during each cycle, always in the same phase of the cycle, as long as the position of the brush is unchanged. By displacing the brush the closure of the circuit can be made to take place at any selected phase.

A current will flow in the circuit and a click will be heard in the telephone if the circuit is closed at all contact places, i.e.:

a. The diaphragm lies against the upper support, i.e., the engine pressure is greater than the balancing pressure;
b. The timer is closed.

By rocking the brush the two limiting phases of the engine cycle, in which condition *a* still prevails, can be found. Tabulating the balancing pressures against the corresponding engine phases, the diagram can be drawn.

This apparatus is accurate, but it requires a comparatively large installation and trained personnel for its operation. Also the telephone detector is inconvenient to use. Lately, in some applications, a neon lamp has been substituted for the telephone, which should give a greater convenience of operation.

For investigating the low pressure phenomena during the exhaust and charging in a two stroke cycle engine Gasterstaedt,[16] in the Junkers Research Laboratory has developed a point by point indicator of the balanced pressure type (Fig. 92) in which the balancing element is a light valve with very short (0.1 mm. = 0.004 in.) lift. Whether the valve lies against one or the other of its two seats, is indicated by two gold leaf electroscopes. The phase at which the pressure is balanced can be sought out by means of a rotating contact in a manner similar to the Bureau of Standards indicator. The data obtained can be plotted in diagram form as shown in Figs. 92b and c.

The "Farnborough" indicator, Fig. 93 (manufactured by Dobbie McInnes & Clyde, Ltd.) is based on the same principle as the Bureau of Standards indicator.[17] It differs, however, in design and also embodies recording means. The balancing unit in this case is not a diaphragm, but a light valve, loaded on the upper side by a predetermined air pressure, and on the lower side by variable cylinder pressure. The moment at which lift occurs is recorded by the breaking of an electric circuit of which the valve forms part. The breaking of the circuit causes a spark which perforates a sheet of paper fastened to a rotating drum running at crankshaft or camshaft speed. For a sparking point the stylus of a large, slow speed pencil indicator is used which is subjected to the same balancing pressure as that acting on the top of the balance valve. As the pressure of the balancing air is slowly raised the sparks produce on the paper a series of punctures forming a pressure diagram on a crank- (or cam-) angle basis.

The error sources of this apparatus are: (a) the time lag in lifting the valve, due to its mass and travel; (b) the width of the valve seat, owing to which the balancing pressure acts on a larger area than do the cylinder pressures. Therefore, both the valve mass and the seat width have to be reduced to the lowest possible value. This necessitates a reduction in the current density in order to reduce chipping of the seat. By carrying these refinements to their possible limits the National Advisory Committee for Aeronautics[18] has considerably improved the accuracy of this apparatus.

The original valve arrangement is shown in Fig. 93c and the improved design in Fig. 93d, the data of which are tabulated as follows:

	A) Original Design	B) Improved Design	Ratio: *Improved* / *Original*
Weight	....	....	1:5
Seat Width, inch	0.034	0.005	1:7
Disk Travel, inch	0.0125	0.004	1:3
Area/Weight Ratio	0.0957	0.475	4:1
Theoretical Pressure Difference Required to lift the Valve, lbs./in.^{2}	253	1.5	1:170

In the improved design the disk and seat are made of stainless steel and can be used for 12 to 18 cards with-

---

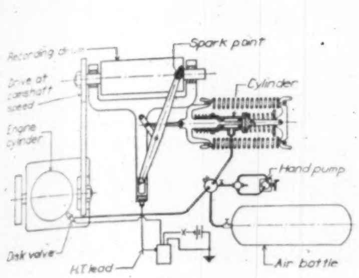
[16] O. Mader. Weiterentwicklung der Junkers- Gegenkolben Maschine. *Zeitschrift des Vereines deutscher Ingenieure,* Vol. 69, Oct. 31, 1925, pages 1369-1378.

[17] M. Wood. R.A.E. Electrical Indicator. *Engineering,* Vol. 115, Jan. 26, 1923, pages 125-126.

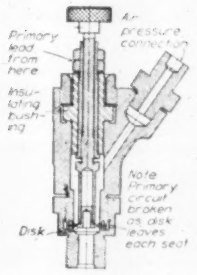
A. W. Judge. The Dobbie McInnes "Farnborough" Indicator. *The Automobile Engineer,* Vol. 15, Jan. 1925, pages 9-14.

[18] J. H. Collins, Jr. Alterations and Tests of the "Farnborough" Engine Indicator. *National Advisory Committee for Aeronautics, Technical Note* 348, 1930, 14 pages.

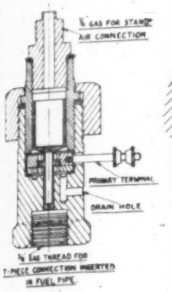
See: E. S. Taylor & C. S. Draper. Discussion of paper by F. L. Prescott. *Journal Society of Automotive Engineers,* Vol. 32, Jan. 1933, pages 41-42.



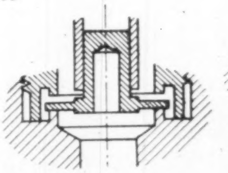
93



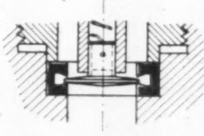
93a


¼" GAS FOR STANDD AIR CONNECTION
PRIMARY TERMINAL
DRAIN HOLE
⅜" GAS THREAD FOR T-PIECE CONNECTION INSERTED IN FUEL PIPE.

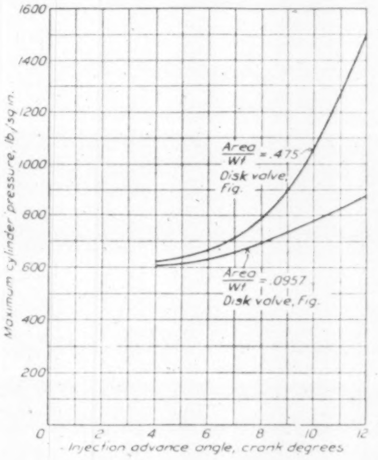
93b



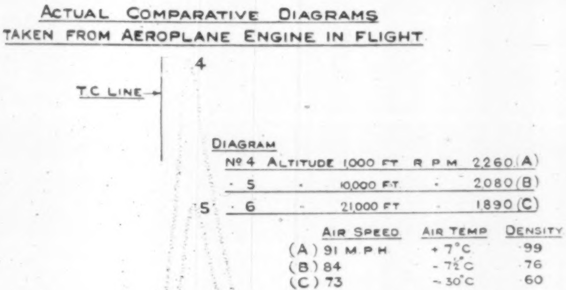
93c



93d



93e



93f

Fig. 93. "Farnborough" Balanced Valve Indicator (Dobbie McInnes and Clyde, Ltd.). Fig. 93a shows the valve unit with the disk valve, air connecting union, and the electrode. Fig. 93b. Balancing valve arrangement by Ricardo for measuring pressure fluctuations in the oil injection line. Fig. 93c shows the disk valve in its original construction while Fig. 93d shows the refined construction as developed by the National Advisory Committee for Aeronautics. Fig. 93e. Effect of disk seat width on cylinder pressures recorded. Fig. 93f is a specimen card taken on an airplane engine at various altitudes.

out repolishing. They can be repolished about 15 times before they are worn too thin for further use.

The electrical circuit to the disk in the original design was completed through a sliding contact with the guide stem. This caused sparking which welded the disk in place and stopped its operation. In the improved design a positive connection was made by means of a copper wire coil (five turns of 0.010″ dia. wire) one end of which is soldered to the spindle and the other end riveted to the disk.

The arcing between the disk and seat was reduced by balancing the circuit with a 0.2 mf. condenser connected across the disk and seat. The detrimental effect of sparking was further decreased by using an inert gas (helium or nitrogen) instead of air for balancing the pressure. The improved performance, as manifested by the higher recorded maximum pressure is shown in Fig. 93e which demonstrates the necessity of careful design and attention to detail in measuring instruments intended for exacting service of this character.

For oil engine fuel injection pressure measurements a special disk valve unit has been developed (Fig. 93b) which may be inserted in the fuel line.[19] It provides a diagram of injection pressure variations on the card together with the ordinary cylinder pressure diagram and simultaneously with it.

This is accomplished by operating the disk valve by two opposed plungers, that on the air side having ten times the area of the plunger on the fuel side. The fuel pressure diagram has therefore one-tenth of the cylinder diagram pressure scale. The ¼″ gas connection is coupled to a pipe leading to the air pipe of the ordinary disk-valve unit. The ⅜″ gas thread at the bottom of the valve can be screwed on to a T-piece inserted in the fuel line.

In the Aeronautical Engine Laboratory of the Massachusetts Institute of Technology another point by point indicator has been developed which embodies a balanced diaphragm and electrical spark recording and as such it combines the features of the Bureau of Standards and the Farnborough indicators. The balanced diaphragm pressure element can be screwed into an 18 mm. spark plug hole and is only a little larger than a spark plug. An important refinement is that the current closed and interrupted by the diaphragm is not used directly for puncturing the card. This current solely forms the part of a vacuum tube relay circuit which is so arranged that it produces a spark at the secondary of the spark coil whenever the diaphragm makes contact. Therefore the primary current through the diaphragm contacts can have a very low value whereby the disadvantageous effect of sparking and welding at the diaphragm is eliminated. Special precautions are taken to avoid backlash and flexibility of the drum drive in order to reduce the scattering of points in the diagram.

The indicator developed by K. J. DeJuhasz in 1919 is based on the phase-to-phase principle, and, in contradistinction to the three instruments previously described, does not require any auxiliary pressure source, nor electrical recording means.[20] Furthermore, it renders possible the drawing of the pressures on either crank angle, or piston stroke basis, at will. The balancing pressure is supplied by the engine itself and a normal, slow speed, pencil type indicator is used for recording. The essential feature of this apparatus is a phasing valve driven positively by the engine under test, which,

---

[19] H. R. Ricardo. Combustion in Diesel Engines. *Journal Institute of Automobile Engineers*, March 1930. On page 8 is described a modification of the "Farnborough" Indicator for the investigation of fuel line pressures.

[20] K. J. v. Juhasz. Uj eljárás gyorsan lefolyó, periodikusan ismétlödö nyomásváltozások vizsgálatára. (A new method for investigating periodically recurring rapid pressure phenomena.) *Dissertation, Budapest University of Technical Sciences*, 1922, 30 pages.

K. J. v. Juhasz. Versuche an einem Automobilmotor. *Forschungsheft zur Auto-Technik*, No. 2, Klasing & Co., Berlin, 1925, 14 pages.

K. J. DeJuhasz. A novel method for testing internal combustion engines. *The Automobile Engineer*, Vol. 12, May 1922, pages 143-144.

K. J. DeJuhasz. The DeJuhasz Indicator. *The Automobile Engineer*, Vol. 15, Sept. 1925, pages 292-295.

K. J. DeJuhasz. The DeJuhasz Indicator. *The Automobile Engineer*, Vol. 19, Aug. 1929, pages 303-307.

K. J. DeJuhasz. Discussion of paper on "Indicator Diagrams." *Journal Society of Automotive Engineers*, Vol. 32, Jan. 1933, pages 42-43.

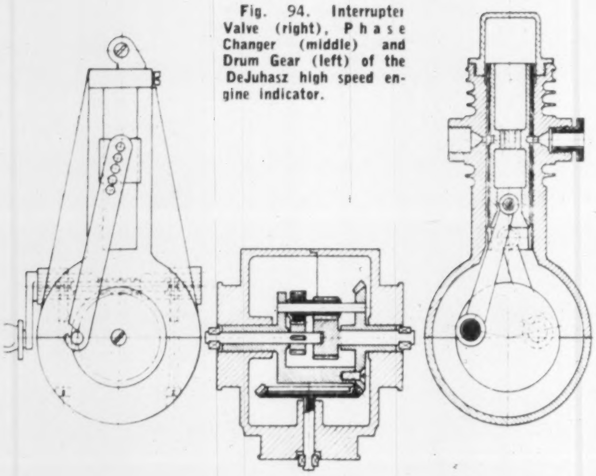


Fig. 94. Interrupter Valve (right), Phase Changer (middle) and Drum Gear (left) of the DeJuhasz high speed engine indicator.

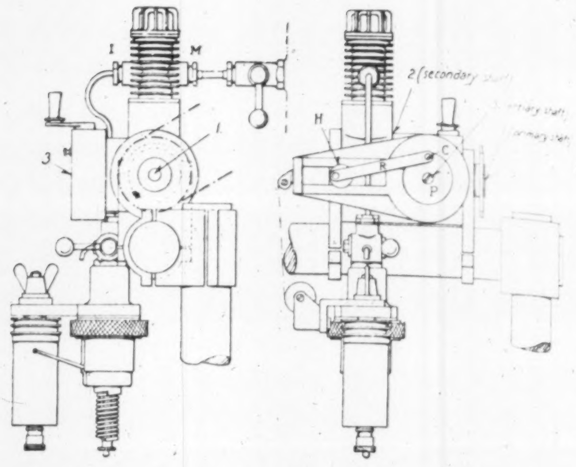


Fig. 94c. Diagram of the general arrangement of the DeJuhasz high speed engine indicator.

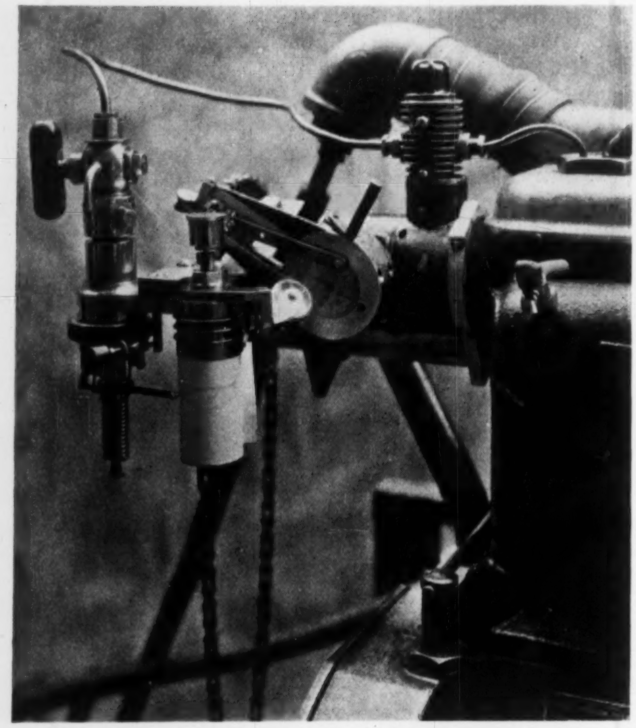


Fig. 94a. DeJuhasz high speed engine indicating apparatus complete with normal external spring indicator, mounted upon an automobile engine on the test bench.

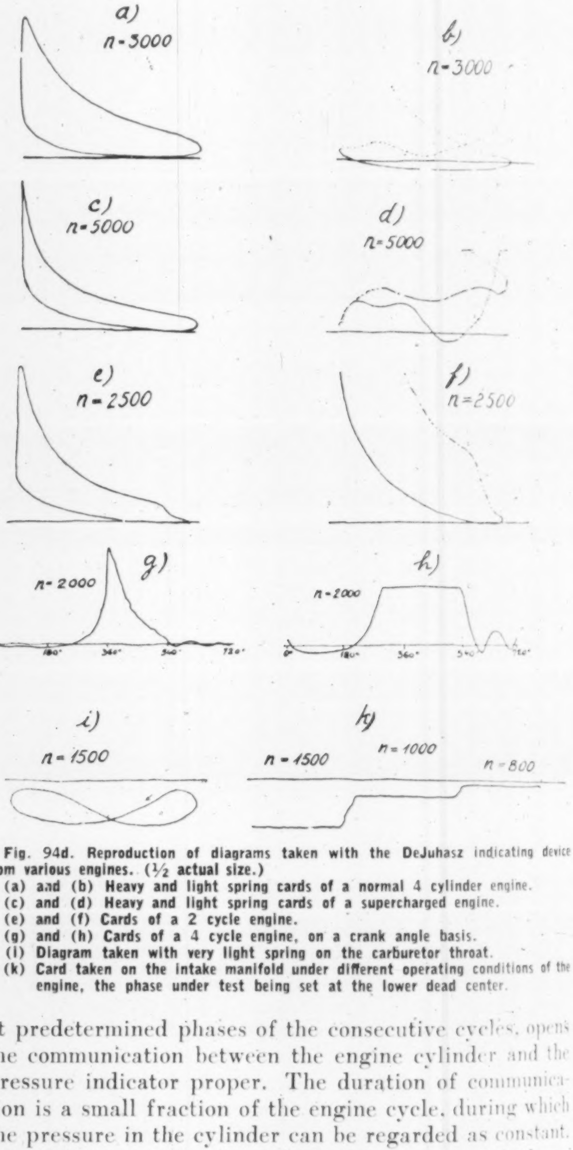


Fig. 94d. Reproduction of diagrams taken with the DeJuhasz indicating device from various engines. (½ actual size.)

(a) and (b) Heavy and light spring cards of a normal 4 cylinder engine.
(c) and (d) Heavy and light spring cards of a supercharged engine.
(e) and (f) Cards of a 2 cycle engine.
(g) and (h) Cards of a 4 cycle engine, on a crank angle basis.
(i) Diagram taken with very light spring on the carburetor throat.
(k) Card taken on the intake manifold under different operating conditions of the engine, the phase under test being set at the lower dead center.

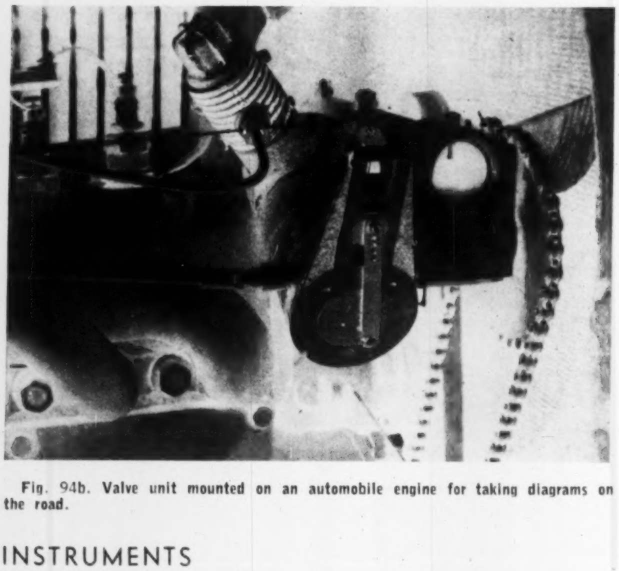
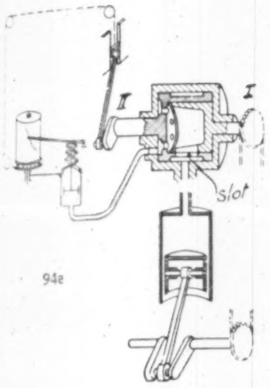


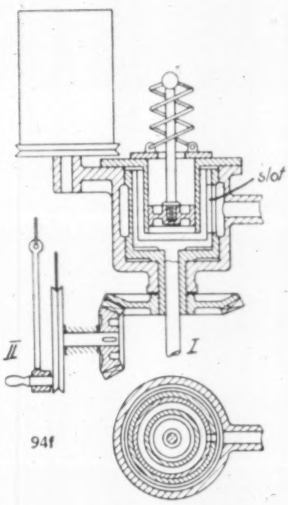
Fig. 94b. Valve unit mounted on an automobile engine for taking diagrams on the road.

at predetermined phases of the consecutive cycles, opens the communication between the engine cylinder and the pressure indicator proper. The duration of communication is a small fraction of the engine cycle, during which the pressure in the cylinder can be regarded as constant. The indicator will then record that pressure which exists within the engine at the tested phase. By changing the phase relation of the phasing valve timing with reference to the engine cycle, another point can be taken, and thus consecutively the pressures in the complete cycle recorded. The change in the phase relation is accomplished by a planetary gearing device similar in action to the differential gear of an automobile. By properly

94e



94f



94g

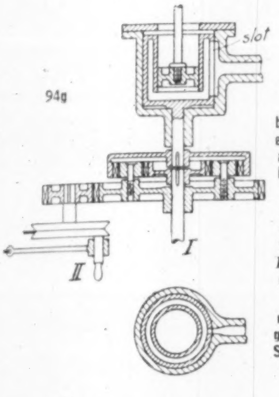


Fig. 94e. DeJuhasz Indicator with double rotary valve. Shaft *I* is driven by engine; Shaft *II* of second valve is operated manually. From this latter shaft the indicator drum is operated.

Fig. 94f. DeJuhasz Indicator showing combination of interrupter valve with the recording indicator. Shaft *I* is driven from the engine; the hand-operated shaft *II* actuates the second valve and also the drum drive.

Fig. 94g. DeJuhasz Indicator showing rotary valve driven through a planetary gearing. Shaft *I* is driven by engine; Shaft *II* is manually operated and effects the shifting of phase.

coördinating the timing of the valve to the movement given to the indicator recording drum the pressure cycle can be recorded as a function of either the piston travel or the crank travel of the engine. Since the speed of both moving parts, i.e. the indicator piston and recording drum is low, the inertia errors are completely eliminated.

The instrument consists of the following main four components:

1. *The pressure measuring indicator,* adapted for this special service, with external spring and interchangeable cylinder and piston sets giving any desired pressure scale. It has the usual recording drum upon which the card is fixed.

2. *The interrupter valve* (Fig. 94) being of the double sleeve valve type, in order to provide a quick opening and cut-off with ample cross sectional area. Freedom from leakage is obtained by careful workmanship, the diametral clearance between the valve units being of the order of 0.0004 in. One outlet is connected to the engine cylinder, the other to the indicator cylinder, by means of suitable copper tubing. This is driven by the "secondary shaft" of—

3. *The phase timing planetary gear,* the "primary shaft" of which is in turn driven directly by the engine by means of a chain, bevel or other positive drive. The "tertiary shaft" of the gear can be turned by means of a worm drive through a hand crank. Thereby an additional rotation is imparted to the secondary shaft. This brings about the changing of the phase under investigation. From the "tertiary shaft" is actuated—

4. *The drum actuating gear* made up of a crank and connecting rod mechanism of variable r/l ratio to be adjustable to that of the engine under test, from the crosshead of which the movement of the indicator drum is derived.

Parts 2, 3 and 4 are constructed in one integral unit as illustrated. The relative position of the different parts can be varied in order to facilitate mounting the equipment on different types of engines and also the interrupter valve can be separated from the rest of the apparatus if the local conditions of the engine tested make such an arrangement preferable. The indicator itself can be placed in any suitable position, away from the engine. The apparatus has been successfully used on engines up to 6000 r.p.m. A few sample cards are shown in Fig. 94d. An error source of this type of equipment is the leakage which may occur in the various pipe unions and in the valve element. Therefore all unions have to be made scrupulously air-tight and the valve copiously lubricated with high viscosity oil in order to provide an effective sealing.

The patent specifications of DeJuhasz describe also other types of the interrupter valve. Fig. 94e shows a rotary valve driven by the engine encased into another rotary valve manually operated. Each of them is provided with a slot; whenever these register with each other the pressure medium can pass from the engine cylinder to the indicator cylinder. By turning the hand-operated rotary valve the indicator drum is actuated thereby as shown in the drawing.[21] Fig. 94f shows the combination of the indicator and the interrupter valve into one compact unit. Fig. 94g shows another combination in which only one rotary valve is used. The shifting of the phase is accomplished with the aid of a planetary gearing.

Of course, any kind of valve, such as poppet valve,[22]

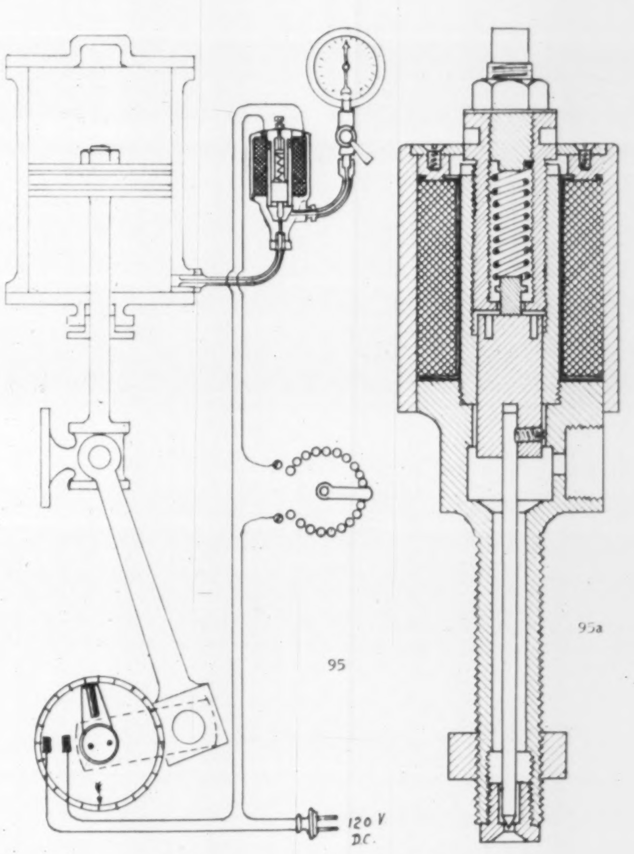


Fig. 95. "Pressure Detector" of Young (Elliott Brothers, Ltd.), with electromagnetically operated interrupter valve. Fig. 95a shows the details of the valve. It is kept on its seat by the spring and is lifted by the solenoid acting upon the iron core attached to the upper end of the valve stem. The valve lift can be regulated by the adjustable stop forming the spring housing.

---

[21] C. H. Gale. The Gale High Speed Indicator. *The Engineer,* Vol 142, Sept. 24, 1926, pages 332-333.

[22] H. M. Jacklin. Some Use of the High Speed Multi-Cylinder Indicator. *Mechanical Engineering,* Vol. 49, May 1927, page 543, describes experiments with a point by point indicator with poppet type interrupter valve. See also:

H. M. Jacklin. Balancing Power Output in Multi-Cylinder Engines. *Journal of the Society of Automotive Engineers,* Vol. 25, Nov. 1929, pages 525-532.

Ford L. Prescott. Indicators as a means of Improving Aircraft Engine Performance. *Journal Society of Automotive Engineers,* Vol. 31, Sept. 1932, pages 361-370.

conical and flat rotary valve, could be used. However, for the service on high speed internal combustion engines the valve has to fulfil a number of important requirements, such as:

a) it is essential that the communication period be a small fraction of the engine revolution, so that the pressure change during the opening period be small;

b) during this short period the valve must provide a large opening area of high orifice coefficient so as to give an unobstructed passage for the flow of the medium;

c) the valve must be free from leakage under high pressure and high temperature conditions. Any leakage constitutes a serious source of error when it is considered that the time available for leakage is a large multiple of the duration of communication. Therefore it is important to avoid distortion from heat which induces leakage;

d) it has to be of small dimensions and weight and of such a shape which permits a short connection to be made to the space to be investigated.

These requirements are best satisfied by the double sleeve valve used in the apparatus as manufactured.

The "Pressure Detector" developed by N. Young in connection with Elliott Brothers Ltd. falls also into this latter class and merits mention owing to its electromagnetically actuated phasing valve. The current is supplied by the aid of a rotary contact-maker in a predetermined phase of the cycle. The general arrangement is shown schematically in Fig. 95.

◆ ◆ ◆

Control of Fractional Horsepower Motors

(Continued from Page 46)

of the motor is not so great as to overheat the motor. Typical control switches of this type are shown in Figs. 3 and 4, which show the mechanism of a float switch, combined with two overload breakers in the same box, for controlling a small 3-phase squirrel-cage motor, and a pressure switch for controlling a pump motor on a self-contained residential water system. Motors so controlled are automatically started and stopped by closing and opening of the switch, thereby maintaining between certain fixed limits the water level, air pressure, coil temperature, room temperature, or steam pressure. These switches have quick-acting mechanisms and double-break silver-to-silver contacts to reduce maintenance and increase reliability. If these switches are installed out-of-doors where they are exposed to the elements, or in damp atmospheres, they should be of water-tight construction.

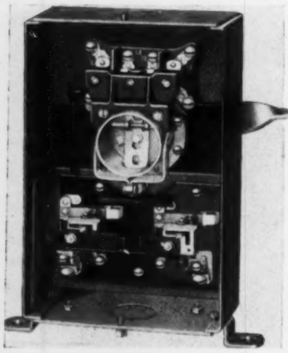


Fig. 3. View of mechanism of float switch, showing three-pole switch and overload breakers. This switch will handle fractional horsepower motors directly and may be used as pilot control in conjunction with an automatic starter.

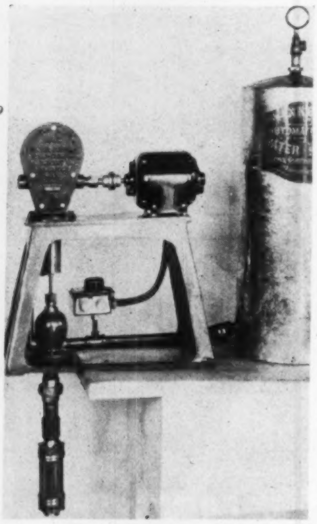


Fig. 4. This small motor-operated automatic water system is controlled by a pressure switch located below the motor and connected to the water pipe through a nipple. Fluctuations in pressure close and open the pressure switch, thereby starting and stopping the pump motor and maintaining the pressure between certain operating limits.

◆ ◆ ◆

READERS' COMMENTS

To the Editor of *Instruments*:

In the April 1932 issue of *Instruments*, there appeared an article by Charles Susa on "Determining Range of Helical Bourdon Springs." In this article he gives formulas for determining the range.

In a paper by H. Lorentz in *Zeitschrift V.D.I.*, Vol. 54, page 1865 (1910) on "The Theory of the Tube Spring Manometer," he gives a formula for determining the amount of rotation for any type of Bourdon spring from measurements of its dimensions. For a Bourdon tube whose thickness is small in comparison to its width the formula reduces to the following:—

$$\frac{A}{A_0} = \frac{1.16\,P\,R_0^2}{h\,E\,b}$$

where A = the angular rotation of the end of the tube.
A_0 = the total number of turns in geometric degrees of the helix or tube.
P = the excess of internal over external pressure.
R_0 = the radius of the helix or tube.
h = the wall thickness.
E = Young's modulus for the material.
b = the thickness of the tube measured from the middle of one wall to the middle of the other.

Applying this formula to the example given in Mr. Susa's article, we get the following:—

The pressure "P"	=	475 lbs./in.^{2}
The wall thickness "h"	=	0.027″
Material	=	Brass
Modulus of Elasticity	=	13,400,000 lbs./in.^{2}
Radius	=	0.5″
Thickness of tube "b" section thickness minus wall thickness	=	0.057″
A_0	=	360°

The results are—

$$A = 2.37°$$

The actual results gave $A = 2.73°$. The discrepancy may be due to the figure used for the elastic modulus of the material since this varies considerably with the degree of working to which the original brass was subjected in making up the Bourdon tube.

The above formula, of course, is only approximate, but none the less, is a much simpler one to deal with than the one given in Mr. Susa's article. The formula is based on first principles in connection with the elasticity of metals, and is strictly true only for a Bourdon tube of elliptical section, but for a very flat Bourdon tube gives results that agree very well with experimental values.

Yours very truly,
THE BROWN INSTRUMENT COMPANY
H. A. ROLNICK,
Engineering Department

Philadelphia, Pa.
February 14, 1933.

"An auspicious beginning of a very extensive undertaking to cover the entire field of instrumentation as applied to the science of engineering." Prof. H. C. Diederichs in MECHANICAL ENGINEERING

FUNDAMENTALS OF

"Practical for the industrial engineer"—POWER PLANT ENGINEERING

INSTRUMENTATION

"A distinct service to the cause of greater efficiency . . . Not so much a treatise on instruments as an introduction to the science of measurement and control."—MAINTENANCE ENGINEERING

BY M. F. BEHAR

"The effects of sensitiveness, lag, sticking and the like are discussed in a manner befitting their great importance and continual occurrence."—Prof. C. W. Gartlein in THE REVIEW OF SCIENTIFIC INSTRUMENTS

$2 POSTPAID

INSTRUMENTS PUBLISHING CO.

Flow Measurement and Control[*]

By M. F. BEHAR[†]

CHAPTER XXVIII

AUTOMATIC CONTROL OF FLUID FLOW

1. What is an Automatic Flow Controller?

"Automatic flow control," in its broadest sense, takes in a multitude of devices and a wide variety of engineering problems. All liquid level controllers, and most pressure and temperature controllers, are "flow controllers" in the broad (and not incorrect) sense of this expression, since they control the flow of fluids. As a matter of fact, the combination of any valve with any device which eliminates manual operation may be said to constitute an automatic flow control system. This is the loosest of technological viewpoints, however, and not that of Instrumentation: As was pointed out in Part One, "before a condition can be controlled, it must be measured" and an automatic controller consists essentially of a primary element or measuring device commanding a valve, rheostat, brush ring or other final element. "If it has no *measuring* element, it is not an automatic controller." We laid down also the principle that any industrial automatic control instrument or system belongs to the particular branch of Instrumentation to which its measuring element belongs. Regardless, therefore, of the various terminologies employed by control instrument manufacturers, Instrumentation declares that an automatic flow controller is one consisting of a flow "meter" commanding a "valve."

This at once rules out of this Part of the Manual numerous devices which *could* be called automatic flow controllers (certain steam traps, for example) and some really excellent systems which *are* so called. This chapter, then, deals mainly with systems embodying fluid meters—with what some manufacturers call "instrument type controllers," an important proviso being that the "meter" measure *rate of flow*. This proviso excludes fluid quantity controllers, such as automatic barrel-filling devices, etc., comprising a meter which does not measure instantaneous rate of flow. The use of the term "meter"—for the part or parts which, in other branches of Instrumentation, are designated as "primary element" is not only appropriate in connection with flow controllers but it is necessary, because in fluid metering "primary element" refers to the part of a meter "which is in contact with the fluid and is acted on directly by it" (A.S.M.E. definition) so that confusion would result from making it refer to the entire meter of a flow control system. Note however that the "meter" of a controller need not always be a true measuring instrument. It need not be calibrated. In some cases it need only "respond" without following any "law."

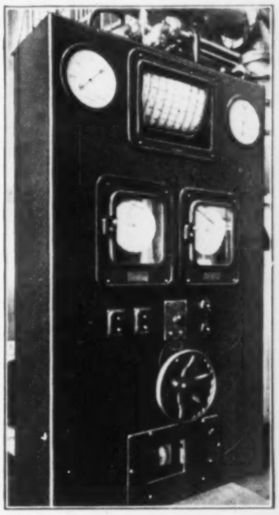
Specifically, then, this chapter is limited to the automatic control of fluid flow rate and mainly to systems embodying meters capable of *continuous* measurement of *instantaneous* rate.

Of flow control it is true—as of pressure control, temperature control, etc.—that the *measuring characteristics* of the measuring element (see Chap. II) influence the *performance* of the controller as a whole (see Chap. III). The metering element of a fluid rate controller is of paramount importance, therefore. In fact, the classification of flow controllers according to the types of their meters is undoubtedly the most useful classification with reference to predictability of the performance modes of control systems being considered for any particular application. However, to avoid repetitions and for reasons which will appear, the author has arbitrarily decided that this chapter should follow an arrangement different from the listing of control systems by types corresponding to types of meters. (The characteristics of the numerous types and sub-types of meters have been discussed in the preceding chapters.) As a matter of fact, in view of the great variety of meters capable of continuous measurement of instantaneous rate, it has seemed best to reduce the meter to the barest essentials and to discuss the other control elements. Fig. 28-1 shows conventional representations of fluid rate meters, any of which could serve

---

[*] Part Six of *The Manual of Instrumentation*.
[†] Engineering Editor.

FOR BOILER CONTROL



THE BAILEY BOILER PANEL gives complete information for controlling boiler operation. It contains the Bailey Boiler Meter, a Bailey Fluid Meter with which is combined a Boiler Water Level Recorder, and a Bailey Multi-Pointer Gage. The operator has everything right before him to obtain the desired capacity and best efficiency at all times. Request recommendations for your boilers.

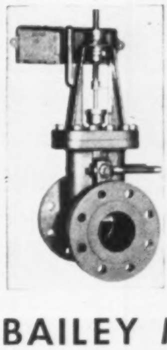
PRESSURE GAGE

400
395
405
390
410
385
415
BAILEY METER CO.

Extremely accurate gages embodying the dead weight gage tester principle are available in several sizes up to 36″ in diameter for indicating at remote points the pressure of steam, water, gas, etc. These gages can be used with any pressures and are particularly suitable for magnified ranges. Ask for Bulletin No. 70.

LONG DISTANCE INDICATOR

Bailey Meter Selsyn Operated Equipment for recording and indicating pressure, temperature, draft, liquid level, etc. at any distance from the source is highly accurate and reliable. Described in Bulletin No. 110.



ADJUSTABLE ORIFICE

The Bailey Adjustable Orifice is for use with Fluid Meter installations where accurate measurements are desired over a flow range of as wide as 160 to 1. Ask for details.

BAILEY METER CO.
1041 IVANHOE ROAD
CLEVELAND, OHIO

MJL INDICATOR
TYPE SERIAL
MOREY & JONES LTD.
LOS ANGELES
CALIF.

INSTANT KNOWLEDGE
of your flow conditions
with the
MJL
FLOW INDICATOR

Dial-type
Flow Indicator

Dial and Mercury column types...These Indicators are applicable for indication of flow-rates of water, oils, chemicals, air, gas and steam under wide range of conditions

Maximum W.P.–Dial type........ 250 lbs.
Maximum W.P.–Mercury type 2000 lbs.

Both types used with MJL Orifice and Flanges...*Write for complete literature.*

MOREY & JONES, Ltd.
Manufacturing Engineers
923 So. Hemlock St., Los Angeles, Cal.

MANUFACTURERS' LITERATURE

In this department we each month list the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter are invited to do so.

A52 **Portable Instruments.** Price Sheet No. 1 for Catalog No. 123 describing d.c. and a.c. portable instruments with steel cases about 6″ square. Roller Smith Co., 233 Broadway, N. Y.

A53 **Balances.** Circulars describing and illustrating torsion balances for laboratory and industrial work. The Torsion Balance Co., 147 Eighth St., Jersey City, N. J.

A54 **Counting Instruments.** A folder describing counters and contact switches for high speed folding machines, etc. Production Instrument Co., 1315 S. Wabash Avenue, Chicago, Ill.

A55 **Machinery Timers.** Bulletin No. 197 features special purpose machinery timers for reversing of laundry machinery, acceleration of large planer motors, acceleration of elevator motors and hoists, flashing of visible devices, etc. Eagle Signal Corporation, Moline, Ill.

A56 **Relays.** Bulletin No. 199 describes rugged, flexible and dependable relays designed for back, front or jack connections. Eagle Signal Corp., Moline, Ill.

A57 **Air Weight Control.** A circular issued by the Foxboro Company, Foxboro, Mass., featuring cupola air weight control which makes possible uniform melting temperatures; elimination of "burnt" iron; 10 to 40% saving in coke, etc.

A58 **Measuring High Pressure.** A leaflet describing apparatus for producing and for measuring high pressure. P. J. Kipp & Zonen, Delft, Holland.

our purpose. Sketch "A" is recognizable at first glance as a head metering element, responding to rate. For this very reason we do not favor it: the meter of a fluid *rate* controller need *not* be of the head class. (Interestingly, "A" is the representation favored by Wünsch in his recent treatment of *Pressure* and *Volume* Regulators.*) Moreover, the ordinary unloaded diaphragm is a notoriously inaccurate measuring element. Weighing all factors, we decided to follow the recommendation of Ed S. Smith, Jr. (co-author of this chapter—see below) and adopt "B," which is as representative of the metering elements of the *flow controllers actually in service* as any schematic drawing could be.

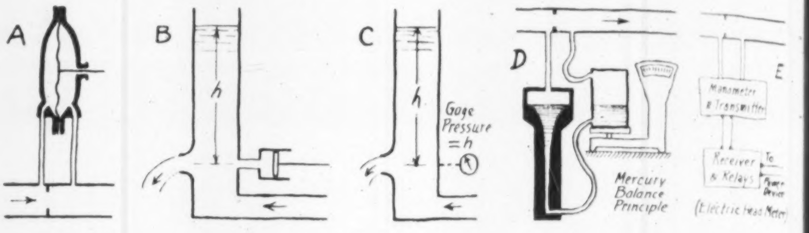


Fig. 28-1

Another way of classifying fluid rate control systems would be by the classes and types of the *final* elements—the valves. Valve characteristics have much to do with controller performance, and some notes on this subject are included in §7.

It so happens, however, that in this field of fluid flow control, (1) few of the meters used successfully for metering are used for automatic control, (2) few of the valves used successfully for hand control and discussed at length in technical literature are used for automatic control and (3) proper control of fluid rate depends largely on *the elements whereby the meter commands the valve.*

The subject under discussion, after all, is not what a flow controller could be: to deal with that subject by merely describing the possible combinations of meters, valves, connecting and operating elements such as pilots, motors, follow-ups, dampers, capacities, by-passes, etc., would add to this book some 200 pages of academic discussions. On the contrary, now that the question "what is a flow controller?" is answered, what is needed is (*a*) a concise practical analysis of the various *practicable* classes of fluid rate controllers, followed by (*b*) brief descriptions of some representative commercially available systems.

(*a*) The required analysis—a work for which there was no precedent in any language—has been prepared by Ed S. Smith, Jr. He should need no introduction to most users of this book, for several original A.S.M.E. papers on fluid metering which he has written have already attained international recognition. Moreover, flow controllers which he has developed are serving in various industries.

(*b*) For the descriptions of commercially available controllers which conclude this chapter (**§8** *et seq.*) the author of this handbook assumes entire responsibility.

ANALYSIS OF FLUID RATE CONTROL SYSTEMS

By Ed S. Smith, Jr., M.E.
Hydraulic Engineer, Builders Iron Foundry

2. Definitions

Due to the characteristics of the flow meter in a flow controller, the difficulty of metering pulsating or transient flows is added to the usual problems met with in the control of temperature and other processing conditions. There is no universally "perfect" mode of control since the requirements of various applications are for different modes of control. For some cases, the most important factor is to keep the momentary deviations of rate within the narrowest possible limits of the desired mean. For many cases, however, it is most important to maintain the average at the proper value—slight momentary variations being of no significance. Fundamentally, there are only a few modes of control that have any general application in rate control of fluids. An analysis, qualitative, is presented that permits the numerous controllers to be judged as to their possible performance, including their inherent limitations. This analysis permits a fair figure of merit to be applied to each.

**Regler für Druck und Menge* by G. Wünsch, chief engineer of the Askania Werke. Chapter XVIII in Part Four (Handbook of Pressure and Vacuum Measurement and Control) contains a condensed translation of this excellent work, and describes some "flow control" systems which the reader will find it interesting to study in connection with the present chapter on fluid rate control.

A few definitions are desirable. A controller of which the valve is operated by the meter without additional power is said to be a self-operating controller and to give "direct control." If the meter releases power from an additional source, the control system is known as a "pilot" controller and gives "pilot control." With direct control the valve is so tied to the meter that hunting is not met with. Pilot control permits powerful forces to move the valve without overloading the meter and impairing its accuracy, so that this class of controllers—comprising the majority in industry—is inherently the most accurate in the sense that proper corrective action is more nearly attained whatever the variables. However, this very fact of increased sensitiveness carries with it a tendency to hunt, unless an additional element, the "follow-up," is added to tie the motion of the valve to that of the meter, preventing over-travel of the valve while the meter is approaching the actual rate. A follow-up connecting the valve and the pilot is the usual form of this device. Thus the follow-up brings the pilot back to its neutral position as soon as the valve has moved the proper distance, so that the valve cannot over-travel and cause a hunting cycle to be set up.

Control is generally either to a "point" or within a "band" or "zone." With point control, the rate will only momentarily be exactly at the point. This mode of control is therefore inherently unstable unless fitted with a follow-up. With band control, the valve goes from open to shut within certain narrow limits of the rate shown by the meter, say over a 3% wide band, considering the full width of the graduated portion of the indicator as 100%. Obviously a controller that operates over a fairly wide band can be stable in operation and still have the valve operate with sufficient speed to meet many commercial cases satisfactorily. However, when precise yet rapid control is necessary, a follow-up and point control form the combination closest to the ideal.

The problem with *ideal* control is to retain the precision of the point control and also the stability that accompanies control over a band with a follow-up. This joint requirement is attained by a "spring" that permits the control to operate momentarily over a band with any departure from the set rate and having a follow-up of the valve movement by the pilot, and then with a "dashpot" gradually restoring the pilot to its neutral point.

3. Classes of Systems, and Modes Obtained

(1) Self-operating Controllers—Direct Control, Non-corresponding.

The meter is directly connected to the valve, *i.e.* without supplementary power, and the valve tends to open wide or shut tight whenever the metered rate differs from that set (point control), so that there is no correspondence between the metered rate and the position of the valve. The meter merely indicates whether the rate exceeds or is less than that set. The valve responds consequently, not to the amount of the difference of the actual rate from the set rate, but merely to the sign of this difference. This mode of control may be either stable or hunting, depending upon the lag of the meter behind the rate of flow. With a lively meter and a proper valve (one with graduated action), the mode obtained will be stable, with the valve steadily maintaining its proper position at all times. However, if the meter lags seriously behind the flow, then the meter will keep the valve in the wrong place at each moment. Hunting will then result from the continuous effort of the meter and hence valve, to follow the flow changes that the controller itself sets up. This control may break down in the final case to "off-on" control, or "two position" control if a by-pass valve is provided around the control valve.

SELF-OPERATING FLUID RATE CONTROLLERS — DIRECT CONTROL

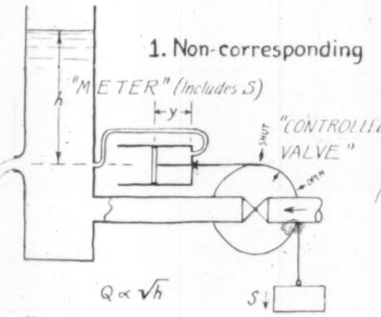


Fig. 28-2

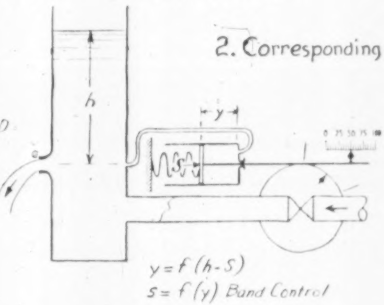


Fig. 28-3

(2) Self-operating Controller—Direct Control, Corresponding.

The meter and valve are again directly connected. However in this case,

A78 **Smoke Tube Draft Gauge** described in catalogue No. 640 is used to make draft determinations accurately and conveniently. E. Vernon Hill Co., 121 N. Clark St., Chicago, Ill.

A79 **Power Plant Apparatus.** An advance circular describes power plant and mechanical specialties. Morey & Jones, Ltd., 922 South Hemlock St., Los Angeles, Cal.

A80 **Spectrophotometer.** A 4-page leaflet describes with illustrations a new apparatus for absorption spectrophotometry. Adam Hilger, Ltd., 98 Kings Rd., Camden Rd., London N. W. 1, England.

A81 **Echelon Cell.** An illustrated booklet describing "The Notched Echelon Cell" which enables absorption spectra to be taken through 10 different thicknesses of solution in one single exposure, yielding on the plate a multiple spectrum consisting of those taken through the 10 thicknesses of solution each together with an appropriate comparison spectrum. Adam Hilger, Ltd., 98 Kings Rd., Camden Rd., London, N. W. 1, England.

A82 **Projector.** A circular issued by the Bausch & Lomb Optical Co., Rochester, N. Y., describes an attachment which enables the lecturer to face his audience and at the same time operate his own machine.

A83 **Precision Balances,** recommended to the textile industry as an accurate and rapid device, in a circular issued by Alfred Suter, 200 Fifth Avenue, New York.

A84 **Draft Regulators.** Two catalogues just issued by The Carrick Engineering Co., Michigan City, Ind.; "High Buildings With Low Fuel Bills" and the other, Catalogue No. 100 on "Carrick Furnace Draft Regulators."

A85 **Photo-Troller.** A new leaflet describing the Photo-Troller and its applications: opening and closing doors, counting objects, "detecting paper brakes" on paper machine, etc., Westinghouse Electric and Manufacturing Co.

A86 **Transformer-Relay.** Bulletin No. 110 describes Mercoid type V Transformer-Relay with sealed mercury contact and low voltage pilot circuit. The Mercoid Corp., 4201 Belmont Ave., Chicago, Ill.

A87 **Tong-Test.** A 6 page folder describing the Crompton Tong Test used to check balance in 3-wire Edison System, in a 3-phase system, to determine the current in individual plating tanks, etc. Baitinger Electric Co., Inc., 95 Chamber St., New York, N. Y.

A88 **Thermostat. Bulletin** No. 25 describes the Hornung "Infiltration" Thermostat. Central Heat Appliances, 343 South Dearborn St., Chicago, Ill.

A89 **Microscope.** Folder on the Unified Slit Ultramicroscope used to simplify the study of colloids. Bausch & Lomb Optical Co., Rochester, N. Y.

A90 **Telescope.** Folder on a utility observation telescope which is easily carried around in its case, slung over the shoulder. Bausch & Lomb Optical Co., Rochester, N. Y.

A91 **Current Meter.** 28-page booklet describes construction and use of Ottmeter Mark V adaptable to almost every condition governing the measurement of water flow. A. Ott, Kempten, Bavaria, Germany.

A92 **Galvanometer.** A circular featuring the Moll vibration galvanometer intended for measuring a.c. of frequencies of from 100 to 2500 cycles. P. J. Kipp & Zonen, Delft, Holland.

INSTRUMENTS, 3619 Forbes St.,
Pittsburgh, Pa.

Please have me supplied with a copy of each piece of Manufacturers' Literature listed below.

....

....

Name ....
Position ....
Firm ....
Street and No. ....
City .... State ....

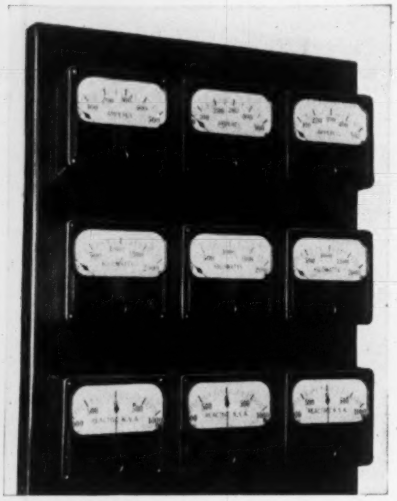
NEW INSTRUMENTS

Write Information Section, Instruments Publishing Company, for additional Information.

Square-Case Instruments

Westinghouse Electric & Mfg. Co.

ARTISTICALLY-proportioned square cases designed to utilize a minimum of switchboard space feature a new line which includes ammeters, milliammeters, voltmeters, millivoltmeters, single and polyphase power factor meters, frequency meters, and synchroscopes. Both a. c. and d. c. instruments are intended for service on large switchboards of steel, ebony asbestos, or slate. Radio frequency and rectifier designs are available for low energy a. c. applications.



The type H case measures only 5½" square by 4 1/16" deep, and the design makes the appearance of a group as pleasing as that of each unit.

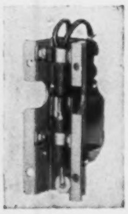
Retaining the fundamentals of design used in previous Westinghouse round-type instruments, the H line has greater overload capacity, the better to withstand severe stresses of short circuits.

◆ ◆ ◆

Vacuum Contact Relays

Ward Leonard Electric Co.

FOR applications where non-arcing, instantaneous and positive contact in the electric circuit are essential features of the switching device, these relays operate on a small amount of current, controlling power-circuits as high as 6 amps. continuously or 8 amps. intermittently, either a.c. or d.c. (non-inductive) at 110 or 220 volts. The vacuum contact is mounted in the metal base and fully protected from accidental damage. Base measures 1½ by 4 in. Depth without enclosing cover is 1¾ in. Obtainable in single and double pole, normally open and normally closed.



the position of the meter indicates the flow rate. Consequently, there is a position of the valve corresponding to each flow rate, provided of course that other factors remain constant. In other words, the further the rate departs from its mean set value, the further will the valve move from its midposition, naturally within the limits set by the open and shut positions.

This class of controllers gives stable modes of control and can be made to hunt only by having an excessive lag in the meter or by having the valve attempt to control over too narrow a band, in which case it will overtravel because the meter lags more in responding to small than to large changes of the rate of flow. Thus the time for an infinitesimal lag is excessive when the width of the control band approaches zero. Here the meter also will not respond to variations that are less than its sensitivity.

(3) Pilot Point Control, Non-corresponding.

The meter actuates the pilot. This in turn controls the supplementary power that moves the valve. This control is to a point since, as in mode class (1), the valve moves as long as the pilot is not at its neutral position. The valve has to operate very slowly, since otherwise it will seriously overtravel its proper position before the meter, and hence pilot, has had time to settle down at the neutral point. In the extreme case this also degenerates into off-on or two position control.

PILOT CONTROL

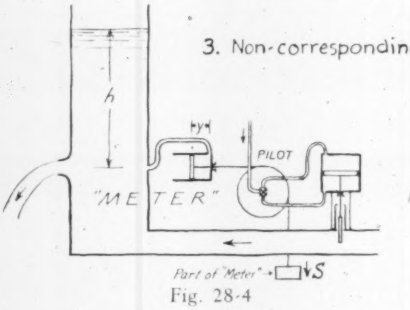


Fig. 28-4

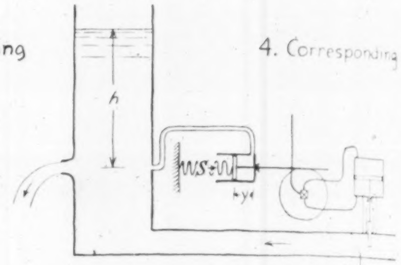


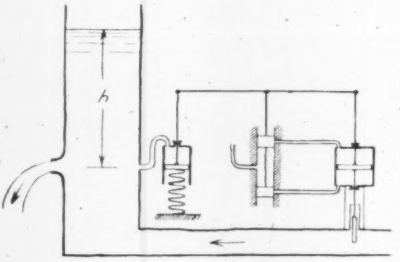
Fig. 28-5

(4) Pilot Band Control, Corresponding.

The meter actuates the pilot, which has the characteristic that the valve position normally corresponds with the pilot position, as with an air-operated controller, when the pilot opening increases, the pressure over the control valve's diaphragm increases and the valve opens a distance depending upon the stiffness of the opposing spring. However the valve position will no longer correspond with the metered rate if any of the following objectionable conditions exist: the control band be too narrow, the valve speed too high, or the meter be excessively over- or under-damped.

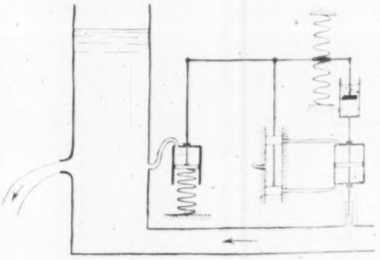
This class of controllers gives modes inherently much more stable than mode class (3) and has some vogue although it is far less stable than any of the following three classes of modes, (5) to (7) inclusive.

PILOT CONTROL — Cont'd



5. Corresponding, with Follow-up

Fig. 28-6



6. Corresponding, with Follow-up, Spring and Dash-pot

Fig. 28-7

(5) Pilot Band Control with Follow-up, Corresponding.

The same elements are used as in class (4) with the addition of a follow-up connecting the valve and pilot. In this way the position of the valve must correspond at all times with the rate shown by the meter. For example if the valve goes from open to shut in 4% of the full rate scale of the meter, the valve would be in its mean position when the rate is correct and be wide open when the metered rate is 2% low; and be entirely closed when the

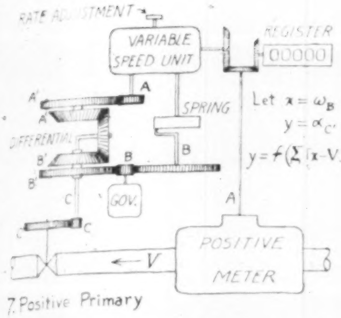


Fig. 28-8

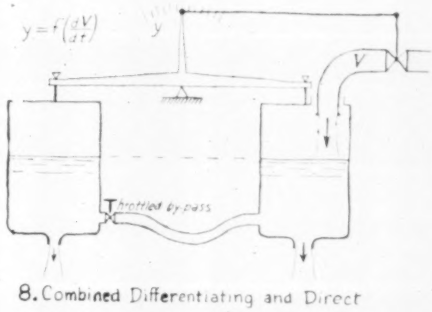

$y = f\left(\frac{dV}{dt}\right)$
y
V
Throttled by-pass
8. Combined Differentiating and Direct

Fig. 28-9

metered rate is 2% higher than that set. This control is adequately stable but the control band is wider than may be desirable.

(6) Pilot Momentarily-corresponding Point Control.

This class uses the same elements as class (5) with the addition of a spring and dashpot that restore the pilot gradually to neutral so that the rate approaches that set. This is generally considered to be the ideal mode of control since it is the most stable of any for any given speed of valve movement and yet controls precisely to a point.

(7) Constant Speed Quantity-rate Control.

A displacement meter has a governor attached so that the valve is operated to maintain the meter at the desired speed. This simple device gives practically the same control as the ideal mode (6). The only difference is that it does not respond quite as rapidly to a sudden change of rate as does class (6), a matter that is generally of no consequence.

4. Elements of Controllers—Meters

Two broad classes of meters are used in governing flow controllers: (1) true meters in which the position of an element corresponds with the rate of flow or some function thereof, such as the pressure differential; and (2) comparative rate mechanisms, having an element that moves in one direction whenever the rate is in excess of that set, and in the opposite direction whenever the rate falls below that set, indicating the "sign" only of the difference and not the magnitude of this difference.

(a) True Meters.

Meters used for pilot control have two principal points affecting the control characteristics: (1) the indicator scale spacing, as to whether even rate or square-root (even differential) spacing is used, and (2) the degree of damping of the meter.

(1) Indicator Scale Spacing.

With the square-root spacing, the working range of the control system is greatly reduced due to the crowding of the graduations at the lower rates. If the control band is of a given width, the corresponding rate variation increases excessively at the lower rates. However, with even rate spacing, the scale is stretched out to its true, normal length at the lower rates.

Again, the upper 20% of the rate is generally used only as a safety margin reserved for the infrequent cases when the flow momentarily exceeds any usual value. With square-root spacing, the 80% rate is at only 64% of the scale so that the upper 36% of the scale is wasted, instead of only 20%. Here again, the superiority of the even rate spacing is evidenced.

With a given damping of a meter, the meter will be much more lively at the higher rates than at the lower. The square-root spacing aggravates this difference by stretching out the scale at the higher rates so that the liveliness of the meter in this region is greatly increased. The even rate spacing, on the other hand, extends the lively action of the wider spacing down into the lower rates where the motion would be far too sluggish with even differential spacing.

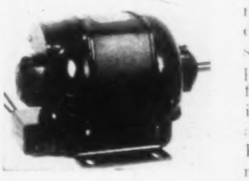
(2) Meter Damping.

Since the meter responds to changes in the flow rate, it must lag somewhat behind them in point of time. The time-lag depends upon the damping of the meter due (in mercurial types) to the friction in the piping connecting the mercury wells, and (in all head types) in the piping connecting the secondary to the primary. An under-damped meter will swing or "surge" past the control point without giving the valve adequate time to settle at its proper position. An over-damped meter will move so slowly that the valve will have gone far past its proper position before the meter has crept up to the control point.

Small Split-phase Motors

The Leland Electric Co.

THIS company announces a line of split phase and also a line of electrolytic start motors, the split phase, type KS, form KSA rigid mounting and KSAT cradle rubber spring mounted; the electrolytic start split phase, type KL, form KLA, rigid mounting and form KLAT cradle rubber spring mounted. Type KS split phase is for applications requiring a motor of quiet operating characteristics, normal torques, and light starting torque. Type KL is for oil burner, stoker, or refrigerator applications where ultra-quiet operating characteristics and moderately high torques are required. In the type KL the box containing the electrolytic condenser is fastened to the top of the motor stator. This box is extremely rigid, and there is no necessity of mounting it separately. Start to run changeover is accomplished by a specially designed mechanical switch similar to that used on type K capacitor. Available in 1/8, 1/6 and 1/4 h.p. ratings.



◆ ◆ ◆

Photoelectric Controller

Westinghouse Electric & Mfg. Co.

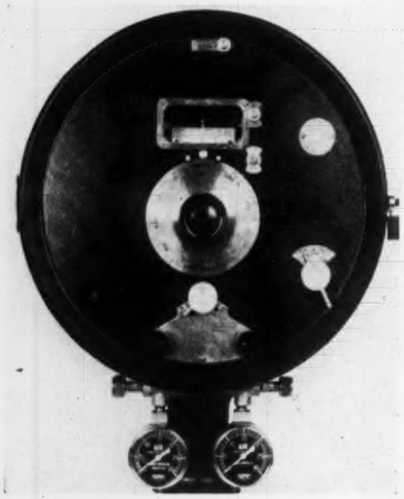
THE new "Photo-Troller" has been developed to meet the need for a rugged industrial device which can be actuated by a phototube or by delicate contacts carrying only a few microamperes. The phototube or sensitive contact operates directly a sturdy grid glow tube which in turn closes a contactor capable of initiating any desired operation. Thus, it is said, greater reliability is obtained "than in any device previously offered."

Units are available for any commercial voltage or frequency except d.c. The device contains a complete power supply for all auxiliaries including the light source. Various light sources are available to operate at distances up to 22 ft. from the phototube. Auxiliary devices are available for adapting the Photo-Troller to unusual machine and process applications. The phototube and light source housings are of cast aluminum and available in splash proof designs for mounting near sprays or in dusty locations.

Potentiometer Stabilog

The Foxboro Co.

COMBINING the many features of Stabilog control and potentiometer temperature measurement, this instrument rounds out the line of control equipment manufactured by its makers. The "100% automatic control" provided by the Stabilog System is now made available for temperatures up to 2800° F. (1500°C.). In addition, the long-distance feature of the potentiometer measuring system makes the instrument valuable where there is a great distance or height between the point of measurement and the controller. Where it is desirable to use this instrument on the lower temperature ranges, the Wheatstone Bridge and resistance bulb measuring system is used. The Potentiometer Stabilog is a non-recording instrument but it is so constructed that a record of its operation may be made on a Foxboro recording potentiometer pyrometer using the same thermocouple. One multiple-point recorder may be hooked up with as many as 6 potentiometer Stabilogs, thus recording and controlling from the same thermocouples.

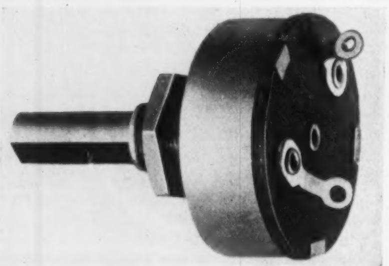


◆ ◆ ◆

Rotary Snap Switch

Wirt Co.

SEVERE tests, it is said, have shown the new "711" single-pole, single-throw rotary snap switch to operate with smooth, positive action and excellent contact with lowest contact resistance. Simplicity of working parts and ease of mounting are said to make this switch especially applicable for radio-receiver assembly. The switch is rated to carry 3 amps. at 125 volts. Underwriters Laboratories listing has been obtained.



Thus the valve's speed is intimately related to the damping for controlling flow. Considering "critical" damping as that giving the most stable control, this desirable condition accompanies the "happy mean" between under- and over-damping.

To achieve stable control, the following procedure may be used: With the valve movement as rapid as seems desirable to meet the departures from the set rate as they occur without reaching serious magnitudes, start with the meter slightly under-damped to travel from the maximum to the minimum control positions within from fifteen to thirty seconds, say. Either slightly increase the damping, or the speed of valve movement until the hunting band slowly narrows down and settles down to a stable control rate. Excellent balance of the controller is indicated when the control will settle down from any reasonably frequent departure with 1½ swings.

It should be remembered however that the entire control system: meter, pilot, and valve, must all be properly proportioned for the particular hydraulic system, or else no amount of patience in adjusting will achieve non-hunting control. Also, many cases require modes (6) or (7) for control stability, and any simple control by mode (3), (4) or (5) is certain to hunt in these cases.

(b) Meters for Direct Control.

For direct control, the meter generally has a diaphragm in its secondary as the differential responsive element, thus combining cheapness with considerable power. The differential is usually balanced against a weight on a beam, but may be opposed by either a spring or a mercury column.

Flat diaphragms are so much less expensive than molded diaphragms in the large sizes used in controllers that the flat diaphragm is almost universally used for this purpose. Unfortunately the effective area of a flat diaphragm changes rapidly with its displacement from its mean position, even when the maximum practicable amount of bagginess is used.

With large controllers for water filtration applications, it is necessary to use a compensating beam so designed that the differential pressure across the diaphragm is constant at all diaphragm positions. Consequently this compensated beam and diaphragm maintains a constant rate of flow for all valve positions.

The time-lag of a flat diaphragm is relatively small, so that diaphragm meter controllers minimize the tendency to hunt.

5. Pilots

(a) Liquid Operated.

A small balanced-piston valve is satisfactorily used as the pilot. A strainer in the supply line is an indispensable element. One time-proved pilot valve design has the following features:

1. Port openings decrease in width as neutral point is approached.
2. Port openings on opposite sides of piston eliminate side thrust, giving complete balance.
3. Supply in center, waste at low (atmospheric) pressure at ends minimizes leakage.
4. Control valve is hydraulically locked in position when pilot is at control point, by having a "lap" on the pilot piston.
5. Power liquid is used only when the rate departs from that set.
6. A throttling plug and by-pass is inserted in one of the lines connecting the pilot to the hydraulic cylinder, thus maintaining full pressure on the control system. This would not be the case were the throttle plug in the supply line.

By opening the by-pass, the main valve can be moved very rapidly to any desired position, as while "cutting in" the controller from hand operation.

(b) Air (or Gas) Operated.

A flapper, vane, swinging nozzle, etc., of minute "needle valve" dimensions, is used to maintain a pressure that acts upon a spring-opposed diaphragm to move the control valve. In most controllers, this needle valve moves a light metallic diaphragm that, in turn, actuates the main supply to the control valve's diaphragm, putting two pilots in tandem. The pressure supplied by the pilot is dissipated by a "leak" in practically all air operated pilot controllers.

Necessary elements for continuous, stable operation are a strainer, moisture-trap and pressure regulator. With two pilots in tandem the need for a follow-up is greater than for the single pilot that may have a corresponding position of meter indicator and valve if the control band is not made too narrow, whereas the two pilots give point control with which hunting is almost certain unless the follow-up be used.

(c) Electrically Operated.

These have the same flexibility and convenience that has won popular use for the electric flow meter. The electric pilot is inherently an off-on control element, but by making use of interrupters, Wheatstone bridge follow-ups, etc., stable control can be readily maintained. An electric flow meter having cyclical operation is ideally suited for operating an electric controller since it "waits and sees what happens" after each valve operation before moving the valve again. This eliminates the incessant valve movement that annoyingly characterizes so many other electrically operated controllers.

Another promising combination is the use of an electric pilot to carry the control intelligence from the meter to a solenoid-operated or similar pilot for a hydraulic- or air-operated controller valve. This would be especially convenient where the meter and valve are at a distance from the metering indicator panel.

Still another combination of potential value is the use of an electric pilot to actuate a motor-driven pump that in turn actuates a hydraulically operated valve, somewhat after the design of the popular G.E. "Thrustor."

6. Follow-up and Interrupter

These devices are invaluable parts of stable pilot controlling systems, not mere optional accessories.

(a) Follow-up

This ensures that the control valve will follow the metered rate, and thus eliminates the hunting that accompanies over-travel of the valve. This concept was taken from the familiar "servo-motor" governor used for accurate speed control of hydraulic and steam turbines.

The meter indicator must be free to move one side of a pilot. The other is attached to the valve through the follow-up. This naturally gives a wide control band.

If a piston-and-dashpot is used in the connecting link of the follow-up, the instantaneous response of the valve to the metered rate is retained and yet the pilot is able to be moved gradually by a slight supplementary force back to its neutral position, thus narrowing the wide band down to a point. Two opposed springs are generally used for this centering operation.

It is possible to introduce cams or linkages to modify the motion of the pilot from that of the valve. This is regularly done with hydraulic turbine governors. For example with a flow meter having a valve that has too steep a gradient, *i. e.*, change of area per increment of travel, when the valve is nearly closed, it would be desirable to increase the movement of the pilot over that of the valve as by a simple bell-crank, using the angularity to obtain the desired multiplication near the closed position.

(b) Interrupters.

With modes (3) to (6) inclusive, more stable operation may be achieved by interrupting the flow of power at intervals so that the meter has time to reach the actual rate of flow resulting from the preceding movement of the valve. This also gives the hydraulic system itself a chance to come to rest and is a worth-while addition for those systems where a follow-up is not included. A meter having cyclical operation lends itself naturally to this stabilizer.

It is interesting to note that a stabilizing effect somewhat similar to that of the follow-up can be obtained by the use of a graduated interrupter so arranged that the duration of the interruption increases as the pilot approaches the control point. In this way it is impossible for the valve to over-travel as long as the controller is reasonably well balanced. This also compares with a pilot in which opening decreases as the control point is approached, with a "lap" on the pilot valve that stops further motion entirely as long as the metered rate is within the "null" control zone, or band.

7. Valves.

For direct control a different valve shape is required from that for pilot control since the self-operating controller must obtain from the meter its extremely limited power to operate the valve, while the pilot systems have ample power available without loading up the meter enough to interfere with its accuracy.

With pilot control the gradient must not be unduly steep near the closed position since the valve speed is about as high here as where the valve is less sensitive. On the other hand, unless a self-operating controller has a fairly steep gradient it will be inoperative from a practical standpoint—the operation will be erratic and jerky. The following brief notes may bring out the causes of this paradoxical situation.

(a) For Pilot Controllers.

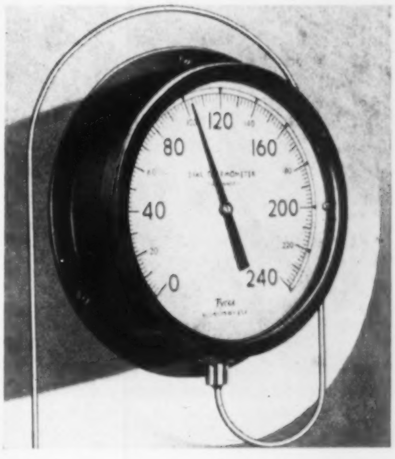
The valve may be of any suitable design—poppet, piston, gate, etc., as long as its hydraulic characteristics are correct, since practically any desired amount of force may be used to operate the valve. The balanced double poppet valve is widely used for small lines. When well constructed, it has

Dial Thermometers and Pressure Gages

Taylor Instrument Companies

AMONG the features of this new line of dial indicating instruments are the following:

Thermometers—Moisture- and dust-proof die-cast case; easily read graduations on 8" silvered dial; balanced wedge-shaped pointer leading eye to indication and minimizing vibration effects; friction adjustment for easy and precise zero setting; hard-bronze pinion and sector with wide tooth faces; phosphor-bronze hair springs; option of heat-treated, chromium-plated alloy-steel movements (at extra cost, to withstand excessive vibrations); option of "Accuratus" tubing for mercury thermometers to be located at great distances from bulbs.



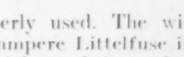
Pressure Gages—Hardened forged-steel chromium-plated sector and pinion with wide tooth faces; hardened stainless-steel bushings for pointer spindle and other parts; movement carried independently of case on plate forged integral with socket; special alloy Bourdon tubes; cases and other new features in common with the new thermometer line.

◆ ◆ ◆

Improved Instrument Fuses

Littelfuse Laboratories

ANNOUNCEMENT of a $100 indemnity protection guaranty on instruments protected by Instrument Littelfuses has been made possible by several improvements in this line, including the use of platinum wire in the finest capacities, which wire is said to be more reliable than the metallized quartz fibre formerly used. The wire used in the 1/100 ampere Littelfuse is the finest in commercial use, being only 1/30th the diameter of a human hair. Rugged mounting for this delicate wire is provided by support wires united with a glass bead. Instrument Littelfuses are made in 11 capacities from 0.01 amp. to 2 amps.



"Watch Type" Double-faced Circular Slide Rule

Aristo Import Co.

RESEMBLING a large but thin stop-watch, a new rotary slide rule which slips easily into an engineer's vest-pocket is said to provide the equivalent of large and costly computing devices. The "A.F. Calculigraph" has 9 fixed and 3 sliding scales and a pair of co-acting hairline pointers. The stem operates the slide or the pointers—the latter when the button is pressed. The A. F. Calculigraph has numerous uses in electrical, mechanical, aeronautical, chemical and other branches of engineering—among them the following: All arithmetic and trigonometric operations, logarithms, electric motor and generator calculations, drop of potential, etc.

Calculigraphe
A. Fischer

◆ ◆ ◆

Midget "Megger" Tester

James G. Biddle Co.

CHARACTERISTICS of this instrument are small size, $5\frac{3}{4}$ x 4 x $2\frac{3}{8}$ in., and small weight, only 3 lbs. In common with other "Megger" instruments, the Midget "Megger" Tester consists of a true ohmmeter, direct-reading like a voltmeter, combined with a special d.c. hand generator. The scale reads as high as 20 megohms and the generator supplies testing current at 500 volts, thus obviating necessity for depending on batteries or any other outside source of current. Special spring plunger-type terminals for rapid attachment and disconnection are provided. There are no projecting or loose parts. The case is molded in synthetic resin with smooth exterior.

the point, sometimes an advantage, that the flow can be shut practically entirely off when the valve is "closed." However, the sleeve, or piston, balanced valve has wide application due to the ease with which the valve ports may be modified to suit the hydraulic system being controlled.

Some combined piston and poppet valves are in control use. The balanced poppet valve also has had the plugs lengthened into conical or paraboloidal portions so that the desired gradient characteristics are obtained. This latter valve may have the practical operating disadvantage that, in certain applications with dirty fluids, the particles may jam in the wedge-shaped openings and jam the valve.

Much has been written in favor of V-ports in balanced piston valves for fluid control, but the *ideal* shape for ports (*i.e.*, that giving equal sensitiveness to valve movement and consequently having maximum stability over the widest range of rates and pressures across the valve with even rate spacing on the meter) has turned out in practice to be a narrow slot that increases more and more rapidly in width as the valve opening increases. This statement considers that a hydraulic cylinder actuates the rate control valve.

A common requirement is that a certain specified maximum pressure drop across the valve be permitted at the maximum rate when wide open. This requirement is readily met with the above variable slot, since the widest portion can readily be made as long as necessary without interfering appreciably with the shape that gives the most stable control over the operating range.

(b) For Self-operating Controllers.

For direct control modes, consideration must be given to every factor that may affect the positioning of the valve since even a small force will affect the accuracy of the balancing meter positioning the valve. The principal forces acting are those due to mechanical friction in moving the mechanism; Venturi, or dynamic effects of the fluid flowing through the valve normally tending to close the valve when it is nearly closed, unbalanced line pressures acting on the valve stem, or valve, the jarring effect of turbulence in the flowing fluid, and finally the presence of foreign bodies in the controller valve may tend to make it jam—so that it must either be self-clearing or else a large reserve force must be available to free the valve.

For smooth valve operation, giving a constant rate of flow at all times, it is necessary to have a fairly steep gradient, *i.e.*, change of area per unit of valve travel. Otherwise, when there is a momentary departure from the set rate, the control valve will not tend to be moved to any definite position.

For controllers, on applications where the loss of head across the valve is of some economic importance, for it may affect the length of time that the units will run efficiently, it is out of the question to use any but well designed, carefully stream-lined valves of ample size. However, for effective control, the drop across the valve is preferably a considerable fraction of the entire head. For such applications, the "best" design must necessarily be a compromise.

(c) Maintenance and Service.

Stuffing boxes for the valve stems are a common feature requiring a certain amount of maintenance although this is generally not serious. Experience in oil refineries indicates that the rotary shaft is less of a nuisance than the push-pull design since less oil is pushed outward and less dirt is pulled inward with the rotary stem, since it obviously merely rotates instead of reciprocating in-and-out. Again, many push-pull stems are made of small diameter to minimize the forces due to high line pressures influencing the operating diaphragm, and these spindly stems have been known to bend when the valve jammed, due possibly to some zealous operator's endeavors to stop all leaks by tightening up the stuffing box. Practically any other stuffing box can be tightened so much as to interfere seriously with the operation of the controller.

Unless a control valve stem has a grease-packed stuffing box, it is generally wiser not to attempt to stop all leakage. In this respect it resembles the stuffing box of a centrifugal pump.

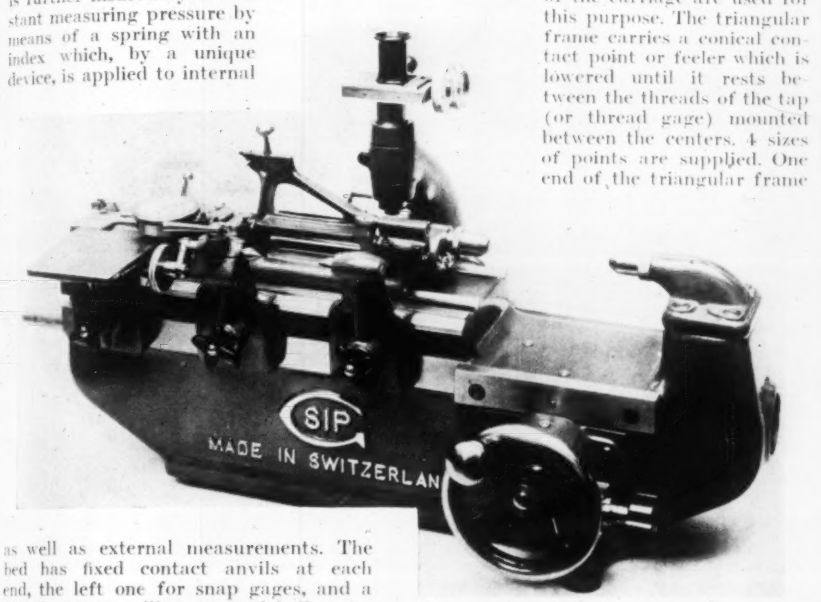
Since the rotary stem may have the end thrust taken by ball-bearings or a niggerhead, and further there is no tendency to move the valve with changes in line pressure, this type has considerable advantages for controllers operating at the higher pressures.

In case a control valve with unsuitable characteristics must be used, it is sometimes possible to use a connecting link between the motor and valve that will reduce the speed of the valve motion over the range in which the gradient is too steep—a simple link and crank mechanism may be arranged to do this.

A certain amount of "service" or initial adjustment may be required in installing a rate controller on a new application in balancing the parts, since full data are seldom available before the controller is actually tried out.

Small Type Universal Measuring Machine

R. Y. Ferner Co.



RECENTLY developed by the Société Genevoise d'Instruments de Physique, this machine has a capacity of 100 mm., or 4", can be supplied graduated in either inches or millimeters and reads to 0.00005" or 0.001 mm. Measurements are made by use of a high precision Société Genevoise micrometer microscope, reading on a special composition glass scale having a temperature coefficient practically equal to that of steel, so that temperature errors are avoided. The scale is standard at 68°F. (20°C.) Accuracy is further insured by a constant measuring pressure by means of a spring with an index which, by a unique device, is applied to internal as well as external measurements. The bed has fixed contact anvils at each end, the left one for snap gages, and a slide between, rolling on steel balls, carries the movable anvils and the glass scale. The latter is $4\frac{3}{8}''$ long. The displacements of the slide are read directly by the measuring microscope to 0.00005" and estimations may easily be made to one tenth of this amount.

Rapid carriage movements are made by the large hand wheel, provided with slow motion for final settings. The anvil at the right end of the carriage and that on the right end of the machine bed are optically flat, 23/64" (9 mm.) in diameter, and made of synthetic sapphire (harder than agate or hardened steel). For external measurements either a flat measuring table mounted on balls, or one carrying centers, similarly mounted, for support of plug and thread gages, is supplied. For internal measurements of snap gages an interesting new method of making contacts is used which permits establishment of the zero setting by pressure of the spring piston against the carriage in the same manner as in external measurements or in the setting on the gap of the snap gage. The anvil on the left end of the carriage consists of two flat-surfaced pieces separated by a gap permitting the other anvil, mounted on the left end of the bed, to pass between and beyond them when the carriage is moved to the extreme left. This movement is carried far enough so that a flat gage, of the Jo block type, 0.2" thick, can be placed between them for zero setting (when a zero check is felt desirable), made in the same manner as the setting on the snap gage. Both are made by movement of the carriage in the same direction as external measurements, and with the same contact pressure. The readings for these internal measurements are also made on the glass line standard in the same manner. A table, for support of the snap gage in these tests, can be set in the proper position for any given size of snap gage.

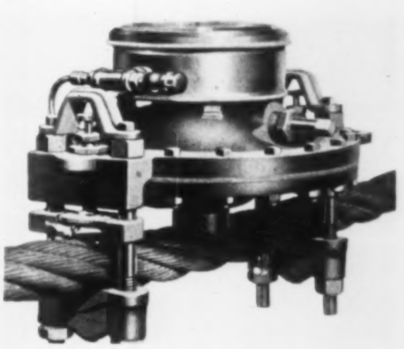
Besides external and internal measurements, the machine provides for measurement of pitch of taps: The center supports at the front, the dial indicator and the triangular framework seen on top of the carriage are used for this purpose. The triangular frame carries a conical contact point or feeler which is lowered until it rests between the threads of the tap (or thread gage) mounted between the centers. 4 sizes of points are supplied. One end of the triangular frame rests against the contact plunger of the dial indicator, the other is pressed by a spring adjustable to counterbalance the dial indicator spring pressure. With the frame thus balanced, the feeler is free to drop to the bottom of the threads; the carriage is then moved until the dial indicator reads zero, upon which a reading is made with the micrometer microscope on the glass scale. Upon raising the framework, moving the carriage and dropping the contact feeler between other threads of the tap, a second reading is obtained, and the pitch is determined. Thus the dial indicator is used only as a zero instrument and any errors of its rack and gears do not enter into the measurement. This attachment for measuring pitches of taps has been found to give an effective precision of 0.00005".

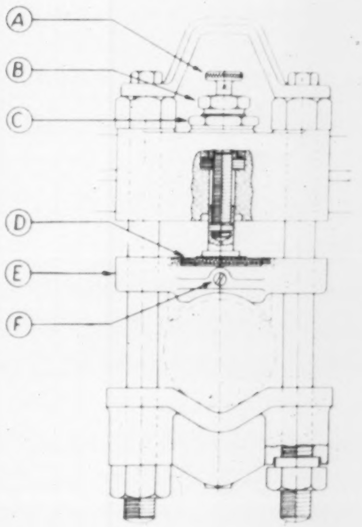
The machine is 25" x 18" x 16" and weighs 128 lbs. The table with centers for measurements of plug and thread gage diameters has a maximum distance between centers of $8\frac{3}{4}''$ and admits plugs up to 2" diam. Flat pieces or disks or the ends of plug gages up to $4\frac{3}{8}''$ can be measured when supported on the flat table. Taps up to $9\frac{1}{2}''$ length can be supported between the centers for pitch measurements. Included with the accessories of the machine when wanted are sets of wires for measuring the effective diameters of screw threads and a pair of prisms for measurements of root diameters. A test certificate of the glass scale is also furnished with the instructions for use of the machine.

Tension Indicators

Martin-Decker Corp.

WITH the addition of a new feeler gage, designed to increase the efficiency of tension indicators, and which is incorporated in the indicator itself at a point underneath the clamping device, it is possible to determine exactly when the instrument is in correct position on the cable for an accurate reading. An indicator recently tested by being repeatedly attached to and detached from a cable showed absolutely no variance. The feeler gage is designed as a knurled edge disk fitted beneath the V blocks which receive the cable. As the clamps are tightened, the disk may be turned freely with the thumb or forefinger until the correct pressure is applied. At this point, action of the disk is automatically retarded by friction against the block. On the heavy duty indicator, to eliminate the need for several deflection plugs to accommodate the different size lines under varying loads, a micrometer deflection adjustor and a saddle adjustor have been devised. The improved instruments may be operated with uniform accuracy and with a considerable saving in time.





A—Micrometer Deflection Adjustor
B—Saddle Adjustor
C—Adjustor Lock Nut
D—Feeler Gage
E—Saddle
F—Micrometer Deflection Adjustment Set Screw

New Circuits for Controls

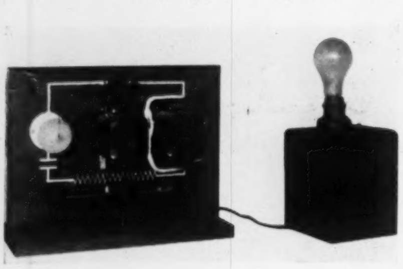
General Electric Co.

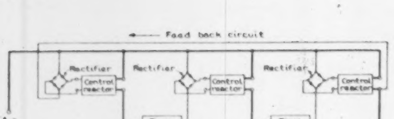
NEW types of controls that flash, dim or brighten lamps, and which require neither moving parts nor electric contacts, can be applied to practically all incandescent-lamp signs and to many industrial applications. Their use on signs reduces operating expense by from 40 to 60%.

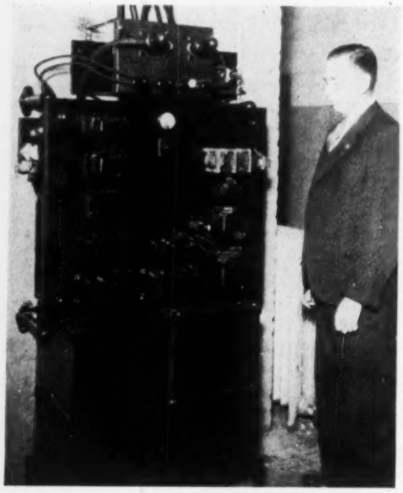
The sequence can be changed readily by simple adjustments. Three circuits are employed now, but more or fewer could be used. Time intervals may be longer or shorter, and a variety of effects obtained easily according to the sequences employed. Intervals may be as small as 1/10 second or as large as 5 seconds between the illumination of successive portions of a sign.

Non-linear Circuits—The sign control, as well as many other effects, is obtained by combinations of saturable-core reactors, copper oxide rectifiers and resistance units, built up into non-linear circuits. These circuits have been produced, and their effects are being studied, by Dr. C. G. Suits in the G. E. Laboratory. Saturable-core reactors are essentially iron-core inductances so arranged that the inductance may be changed by saturation of the core material with direct current. One watt in the d.c. winding is sufficient to control 100 watts in the a.c. circuit; the method of control is from 85 to 95% efficient; and practically unity power factor operation is provided. An important property of the saturable-core reactor is a time delay factor that is required for substantially full-load voltage to appear after the direct current is applied. This time delay, which may be varied, provides sequence operation independent of the thermal characteristics of the lamps. Feed-back circuits are employed to cause sequences to repeat, or commutate. The load reactors are also the control reactors; auxiliary control means are not required. The circuits are entirely free from radio interference, and are silent in operation.

Other Types of Circuits—Recent experiments in the laboratory have brought to light non-linear circuits which are oscillators, in such respects functioning like vacuum tubes. One circuit produces such slow oscillations that an incandescent lamp placed in the circuit is turned on and off several times per second or as slowly as once in 30 seconds. One such oscillator has blinked a light on and off silently, without radio interference, and without wearing parts, approximately 100,000,000 times while on life test.







Another oscillator produces relatively high-frequency alternating current. It was known for some time that high frequencies could be produced in transformers under certain conditions, but these frequencies are always multiplied or integral fractions of the frequency of the power supply. The new oscillator will produce any frequency in its range; 5,000 cycles/sec. already having been observed audibly.

Still another application of non-linear circuits has been in resonance relays. Such relay circuits, which function because of "voltage resonance" and "current resonance" principles, are so sensitive that a voltage change of as little as 0.01% will cause a current change of 100%. Relays of this type are adjusted by changing electric constants rather than mechanical constants, and are therefore practically free from the effects of wear, friction, dirt, and extremes of temperature; the burden of accuracy is placed on a circuit, where accuracy may be obtained economically with perfect reproducibility.

◆ ◆ ◆

Cambridge Pot Galvanometer

Cambridge Instrument Co.

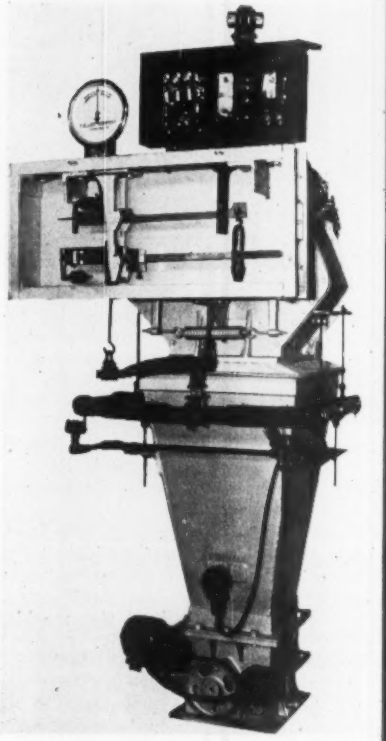
A GENERAL use instrument designed for general laboratory applications as well as educational purposes, this new galvanometer is provided with a pointer scale and a reflecting mirror. It is of the moving coil type, the coil in the shape of a square, held in position by two phosphor-bronze suspensions, the bottom suspension fastened to a flat spring to provide proper tension. The coil carries an 8 mm. diameter plane mirror; the window in the case is a lens with a 1-meter focus. For the pointer a scale 8 divisions each side of zero is provided and is figured 5-0-5. The galvanometer is furnished only with a coil of 50 ohms resistance, this giving a sensitivity of 30-0-30 m. a. on the pointer scale. At a mirror scale distance of 1 meter 1 m. a. gives a deflection of 12 mm. The period is approximately 1.3 second, giving a factor of merit of 140. A zero adjustment is provided. The instrument is robust and requires no leveling or clamping.

Automatic Cement Batchers

Fuller Co.

ENGINEERS and contractors require a limit of error of 1% in mixing concrete. Two new batchers, one fully automatic and the other of the manual weighing type, built to the 1932 New York State specifications for accuracy and tamper-proof operation, fulfill all requirements of the industry. The machine illustrated has a hopper capacity of 11 cu. ft. and the standard machines have batch capacities up to 4000 lbs. for materials equivalent in weight to portland cement.

This machine has a number of interesting operating features. Although it is started and stopped by remote control, it is also operable as a continuous weighing device to run until a predetermined quantity of material has been weighed and discharged, as for car and truck loading.



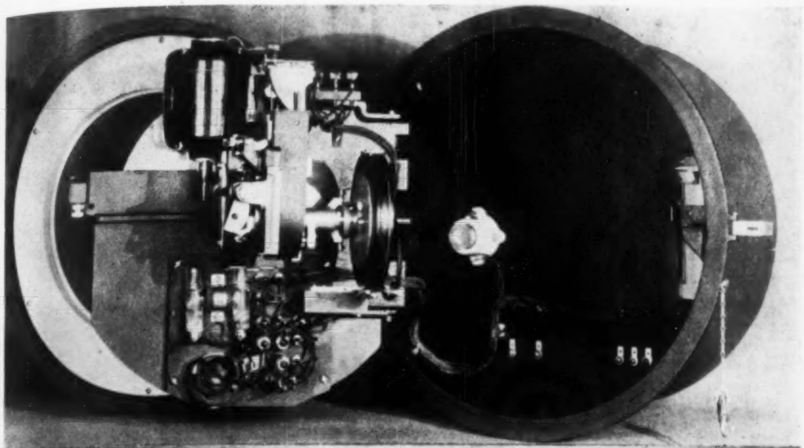
After the counterpoise on the scale has been set for any desired batch weight, the operation is started by a remote control switch. As soon as this circuit has been completed, further operation is entirely automatic, and the apparatus cannot be stopped or discharged until the exact weight of material has been deposited in the hopper.

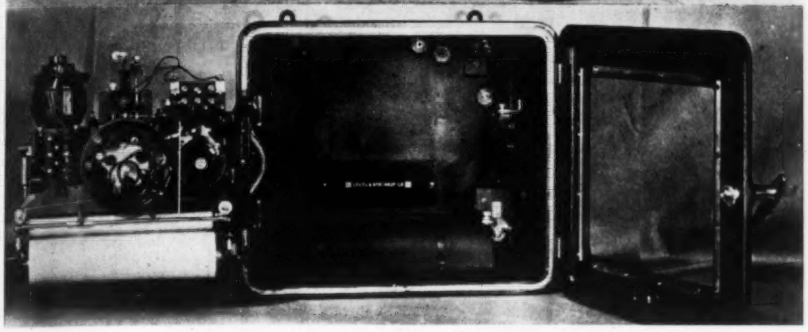
The apparatus cannot be discharged if the actual weight of material is more than ½% in variance, although the engineer in charge can modify this if he should desire to.

The tendency of pulverized materials to flush or flood through minute orifices and thereby disturb the process of weighing, resulting of course in overweights, has been overcome by the use of a non-flooding, volumetric measuring feeder.

New Industrial Models of Recording and Indicating Potentiometers

Leeds & Northrup Co.





TWO new multi-purpose industrial instruments—each embodying essentially identical "Micromax" electrical measuring systems of the automatic null method class—have been brought out by the above company.

One is a new round-chart Micromax Indicating Recorder. This "junior" instrument is not capable of all that the strip-chart Micromax can do, but is said to bring the reliability and the relatively easy, low-cost maintenance of the motor-driven null recorder to a price class that has never enjoyed these advantages before. This is especially valuable in pyrometers of about 400° to 900° or 1000°F. range, because of characteristics such as, first, the thermocouple or resistance bulb has long life; second, it may be replaced without sending the recorder back to the factory, and, third, it may be installed at any distance from the indicating recorder or shifted from place to place at will. This combination instrument is also adapted to the recording of temperatures in the entire ranges of thermocouples and of resistance thermometers, to the recording of smoke density, liquid levels, SO_2, speed, solar radiation, etc. Among its features are the following: A boldly-lettered circular scale that can be read at a glance across a large room. A 24-hour circular chart with straight-line time coördinates instead of curved ones, thus increasing the readability of the records. The calibrated portion of the chart is 3½" wide, and the chart is 10⅜" in diameter overall.

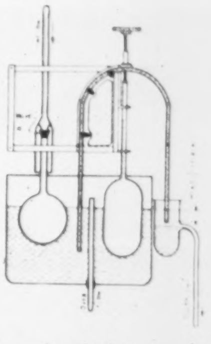
The recorder is made as a single-point instrument only, and can be equipped with two signal or control contacts. Potentiometers are manually standardized. The mechanism, mounted on a frame that is hinged to the case, may therefore be swung out of the case if desired. The case is 16½" diameter, and may be mounted either flush or hanging on the face of a wall or panel.

The other new equipment brought out by above manufacturer is a multi-purpose case for the Micromax Recorder. This case is dust-tight (and vapor-tight when desired), and can be supplied for mounting either flush in panel, on front of panel or wall, or on table or bench. It is sealed by turning the handle, thus pressing the door tightly against a rubber gasket. The lock is outside the gasket, and hence vapors cannot filter into the case through it. The switches for motor, lights and control circuits are operable externally, and are vapor-proof, so that these units may be shut off before the door is opened and outside vapors reach the mechanism. Leads to the recorder can be brought in through either conduit connections or a pothead. The mechanism can be swung completely out of the case, and it then is accessible from all sides.

DEG. FAHR
40
50
60
30
70
20
80
10
90
0
100
MICROMAX

Solution Feed Equipment

Phipps & Bird, Inc.



A NEW device for feeding solutions at a constant rate possesses simplicity, corrosion resistance, constancy of feed and complete accessibility of all parts for cleaning or replacement. A siphon is mounted on a parallel motion hinge, the free end of which is carried on a float in the tank from which solution is fed. The solution flows to the feeding tank under the control of a float valve, which throttles the inflow of solution to the rate at which the siphon is feeding. The rate of feed depends on the difference in level between the solution in the tank and the outlet end of the siphon. A convenient screw is provided for adjustment to the desired flow. The output of the siphon is caught in a glass vessel formed to serve as both a funnel and a trap. When the supply to the feeder is stopped, this trap seals the open end of the siphon and causes the siphon to be kept primed in readiness to commence feeding as soon as the supply to the apparatus is restored. All parts of the apparatus can be dismantled for cleaning with no other tool than a screw driver.

Two pieces of accessory apparatus have been designed. One is an automatic valve for switching the feed from one solution supply tank to another when the first runs dry. (This is not necessary where feeding is intermittent or conducted under supervision.) The other is a pressure filter which can be used to remove suspended matter from the solution to be fed.

◆ ◆ ◆

Apparatus and Instrument Supports

S. D. Bryden

RIGID, light weight supporting frames and panels of many sizes and shapes are readily assembled from 6 standardized lengths of angle members, one size of gusset, and one size of bolt. All parts are of non-magnetic, rust-proof 17ST aluminum. This alloy has approximately the same yield point as structural steel. The angle members vary in length from 7 to 41" and carry a combination of holes and end slots so that they may be used interchangeably as corner posts, main rails, cross rails, risers, and diagonals. Apparatus and instruments used for research, instruction, lectures, exhibition and museum displays, etc., may be supported directly by the angles and gussets, or indirectly by newly devised clamps, and by combinations of rods and the many types of existing laboratory clamps, etc. Parts may be obtained finished either in their natural heat treated color, polished, or in the protective and colored coatings of Alumilite.

The Anubis Differential Pressure Indicator

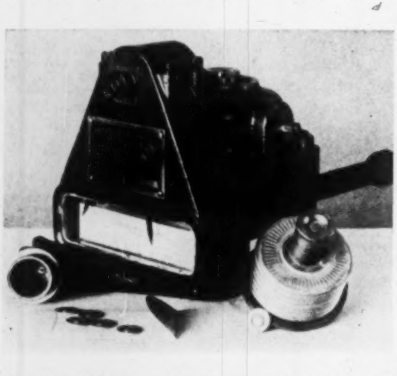
By George Sidney Binckley

DEVELOPED to meet the need for an instrument free from limitations inherent in various types of dial indicators or liquid manometers heretofore used, this new instrument employs principles widely different from those previously made use of. No mercury or other liquid column is used. Instead, the 2 pressures act on the outside and inside of a strong but highly elastic spring phosphor bronze bellows mounted in a pressure chamber. The movement of the bellows, strictly proportional to this difference, is transmitted to the outside of the pressure chamber through the elastic deformation of a special alloy steel "torsion tube" the closed end of which is within the pressure chamber, all pressure being external to this tube. The open end of this tube is outside the pressure chamber, to which it is firmly locked.

The movement of the head of the bellows, due to the differential pressure, is transmitted by purely mechanical means through the wall of the pressure chamber without any opening whatever through this wall, and with a total absence of friction, as there is no metal-to-metal rubbing contact inside the pressure chamber, all motion being that of elastic deformation of the phosphor bronze bellows and tension ribbons, and of the spring-metal "torsion tube." The employment of this unique principle affords unprecedented sensitivity to slightest variations in pressure, absolute freedom from leakage, and total absence of friction even in the pointer mechanism.

To protect the bronze bellows against damage from an excessive differential, automatic relief is provided by a breaking disk of lead, about 9/16″ diam. and 3/64″ thick, which has pressed in its surface a V-shaped groove leaving an unbroken thickness of about 0.005″ of lead. This disk is held in place by a screwed and knurled retaining ring of brass, under a screwed cap in the head of the pressure chamber. If a disk is blown, this cap is removed, the blown disk replaced and the instrument put back in service in 2 or 3 minutes at a cost of a few cents for a new disk.

The principle under which this breaking disk operates is in itself unique, for although the actual ultimate strength of the disk under direct fluid pressure averages about 100 lbs./in.^{2}, it can be adjusted to blow at a differential pressure of less than 10 lb./in.^{2}. This is made possible by 2 "firing pins," one in the cap and one in the pressure chamber, so arranged that if a differential in excess of say 15 lbs./in.^{2} is reached, the bellows itself forces the disk against a firing pin and pushes out the center of the disk. This has never failed to give perfect protection, even under extreme conditions of suddenly applied and excessive pressures.



Anubis indicator and parts. At right, bellows and breaking-disk mount. At left, cap with "firing pin" inside. Cap has been removed from head of pressure chamber, exposing top of breaking-disk mount. In foreground, a few spare disks.

The instrument is provided with a red pointer which may be instantly set to any point on the scale, so that the operator can see at a glance just how far the black pointer—indicating the actual flow or level—is from normal. The scale is graduated evenly in inches of water, etc., or quadratically for reading of liquid flow, or percentage of maximum flow for gases. The movement case is dust- and rain-proof, and its cap is sealed after calibration. The zero adjustment of the pointer, after the instrument is set up, is the only one that need be made.

Special alloys are profusely used. All joints are male and female, with thin, narrow gaskets. All Anubis Indicators are subjected to a proof test in the laboratory. Many have withstood 1,000 lbs./in.^{2} of *kerosene oil* without showing any leak whatever. Some have been furnished for *working* pressures of 1000 lbs.

◆ ◆ ◆

Automatic System Supplies Proper Air Weight to Cupola

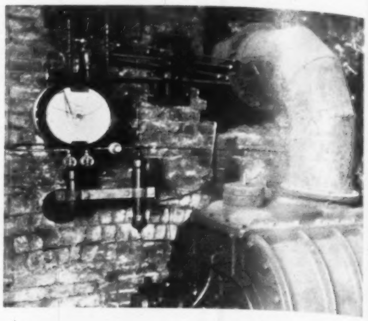
The Foxboro Co.

NORMAL variations in barometric pressure and in air temperature cause the weight of oxygen per unit volume of air to vary by as much as 20%. Thus the proper control of the melting of ferrous materials (and of other processes calling for precise adjustment of oxygen supply rate) has heretofore been difficult—if not unattainable—with *volume-rate* devices.

The new Air Weight Controller comprises a temperature and pressure compensating mechanism which provides a continuous indication of the *weight-rate*. This is achieved by the "continuous sampling" method whereby a small portion of the air supply flows through the air-tight case and allows the compensating mechanism to respond to line pressure and temperature with practically no lag.

Consequently, the instrument does two things. First, its pen records the weight-rate—or the air flow rate expressed in *standard cubic feet* (n.p.t.) which is equivalent. Second, it commands a diaphragm-motor or other power device whereby the gravimetric quantity-rate of air delivered to the blast furnace, cupola or other processing apparatus is automatically regulated.

The new Air Weight Controller can be used in conjunction with practically any type of blowing equipment. When used to control the air flow to a cupola, an orifice plate or other primary device is installed directly in the blast pipe and the instrument commands a butterfly or other suitable valve. In controlling the flow to a blast furnace, the orifice plate is located on the suction side of the blower. The control mechanism can be arranged to command the turbine or blowing engine governor so that the desired quantity of air will be delivered with the least consumption of fuel. An alternative installation is to place the controlled valve in a bypass line around the blower. The entire control equipment can be installed in a few hours by an experienced pipe fitter.



◆ ◆ ◆

Cold Bend Testing Machine

Baldwin-Southwark Corp.

THIS device was developed by Professor C. H. Scholer, Kansas State College of Agriculture. After a study of commercial cold bend testing devices, it was seen that an ideal device of this kind should have the following characteristics:

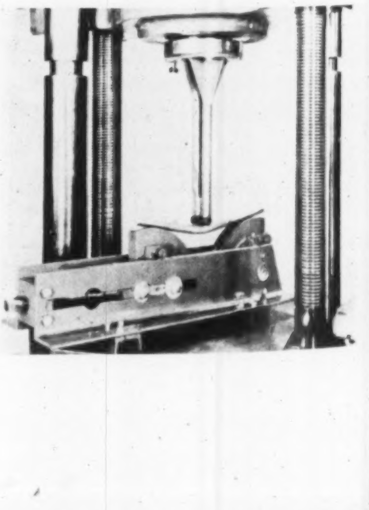
(a) It should bend the test bar around the pin specified with the least possible force.

(b) It should, in testing, introduce no lateral forces.

(c) Control of speed of test should be inherent in the scheme.

(d) It should be adaptable to short specimens and not require a special construction of test bar.

The device is adaptable to any type of testing machine having facilities for compression testing. It consists of 2 cast iron segmental rollers of 6″ radius mounted on hardened steel pins 2″ in diameter. These are mounted in a frame of standard steel angles. One bearing is made adjustable. The upper edge of the frame is graduated in inches. A pointer indicates the distance between the faces of the segmental rollers. The total weight of the device is 175 pounds. Load is applied by a column consisting of two 1½″ steel rods welded to a base plate fitted with clamps for attachment to the spherical head of the testing device. The other ends of the rods are welded together and grooved to hold the hardened steel pins around which the bar is to be bent. To bend a bar through 180° requires a movement of 6″ plus the diameter of the bar plus the radius of the pin. Bending will always start with a span of 12″ plus the diameter of the pin plus twice the thickness of the bar. This long span causes the bar to bend with relatively low loads



Bailey Escapement Integrator

Bailey Meter Co.

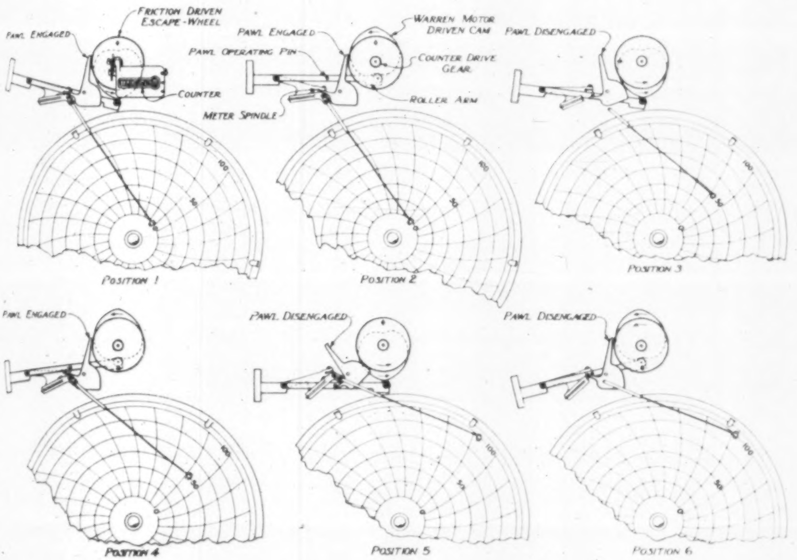
THE total flow registered by this integrator may be read directly on a six-unit counter visible through a small window in the meter name plate. The principal operating parts and the operating principle are shown in the series of diagrams. The heart shaped integrator cam, which has a uniform angular rise, is geared to a Warren Synchronous Motor and rotated at 2 r.p.m. By means of a friction clutch between the cam and the escape wheel, the motor drives the escape wheel and integrator counter at constant speed when the pawl is not engaged. As the pawl engages with the escape wheel the integrator counter is held stationary, but the friction clutch allows the cam to continue rotation.

The roller arm is pivoted near its left end to the flow arm so that the position of the pivot varies only with changes in the rate of flow. The right end of the roller arm moves up and down due to the action of the rotating cam, causing the pawl operating pin to move up and down also. It is this operating pin which is responsible for engagement and disengagement of the pawl with the escape wheel.

Positions 1 and 2 show the flow recorder at zero rate of flow. In 1, the cam and roller arm are at maximum throw, and in 2 they are at the point of minimum throw. In both of these zero rate-of-flow positions, which represent extreme cam positions, the integrator counter is stationary because the path of the pawl operating pin does not come sufficiently low to disengage the pawl. Positions 3 and 4 also show the cam and roller arm in their extreme positions, but the flow recorder is now at 50% of maximum capacity. Under these conditions, the integrator runs 50% of the time.

Positions 5 and 6 show the cam and roller arm in similar positions, but with the rate of flow increased to 100% so that the integrator runs continuously.

This escapement integrator is accurate inasmuch as its operation is governed by the rate of flow at each engagement and disengagement of the pawl. The integrator total is adjusted to the prevailing rate of flow 4 times each minute instead of only once as with the ordinary type of intermittent integrator. This new escapement integrator is included on all Bailey integrating meters of the new type.

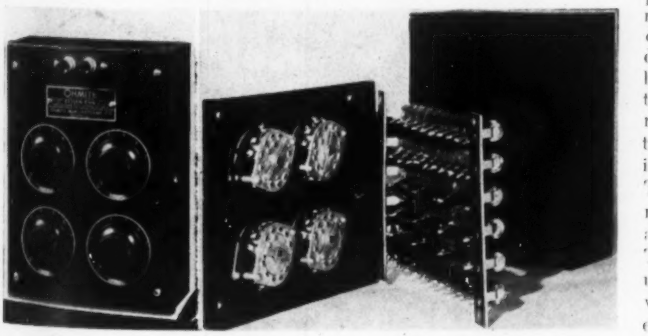


◆ ◆ ◆ ◆ ◆

Four-dial Resistance Box

Ohmite Mfg. Co.

THE "DETERM-OHM" (so named because its chief purpose is to determine radio replacement resistor values) is a new resistance box for radio service men, radio and electrical engineers, laboratory technicians, and experimenters. By manipulating 4 direct - reading dials, it is possible to obtain actual resistances ranging from 100 to 1,000,000 ohms in 100-ohm steps. The guaranteed resistance tolerance is ± 5%. The resistance units are of the wire-wound, coated type—a construction different from that of the type of box which uses low wattage carbon resistors, and which can be used only for meter measurements. The Determ-Ohm may be connected directly in a radio circuit in order to find the proper resistance value required at the points of connection. In many cases the radio serviceman finds that a resistor in a set has been completely destroyed, and that it is impossible to read the value of the unit or to measure it. In such a case, the Determ-Ohm is connected in place of the defective resistor, and the resistance reduced until the set functions properly, when the dials will show the proper replacement resistor value. Other uses include the increasing of voltmeter ranges, as resistance bridges, as ohmmeters, as milliammeter resistances, etc.



◆ ◆ ◆

An Electric Taster

Westinghouse Electric & Mfg. Co.

THE Electrynx, recently developed by R. C. Hitchcock, electronic engineer of above company, indicates the ripeness of fruits and vegetables by measuring their acidity. It also registers the acid content of tea and coffee. By its use, it is claimed, canners and preservers will be able to keep the flavors of their products at a given standard because it will be possible for the samplers at the various orchards and fruit exchanges throughout the country to select the raw product more scientifically. With the further development of the Electrynx, and when accurate charts are made as to the microamperes of the various products under investigation, no doubt the whole system of testing and sampling will be revolutionized.

It is predicted that with further development of this new apparatus, "the days of sticking out your tongue to the medical doctor is past," for the acid content of a patient's tongue will be indicated.

The principle dates back to Volta and his "wet" battery. The 2 dissimilar pins used in the Electrynx are the electrodes and the materials under test supply the electrolyte.

This device is sensitive to 1 microamp. Previous recording meters of this sensitivity were expensive and not readily portable. Direct electrical measurements can also be made which formerly required elaborate circuits or amplifying devices.

◆ ◆ ◆

New Electric Metering Unit

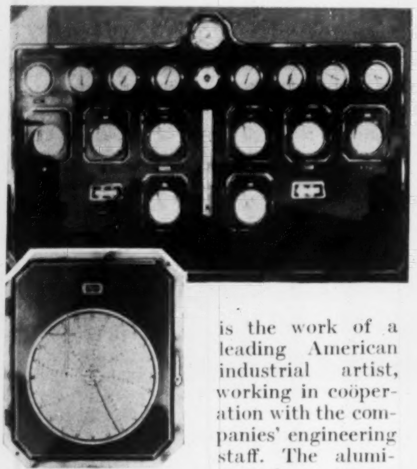
Westinghouse Electric & Mfg. Co.

THIS compact, self-contained, metering unit for especial application on 120/208 volt, 3 phase, 4-wire network systems is totally enclosed, and hence theft-proof. Inside the cabinet are three through type "high-accuracy" current transformers having cores of Hipernik. On the front panel is mounted a polyphase watt-hour meter and a complete test switch. Line leads pass through the insulating tubes and current transformers, and neutral lead through the bottom opening. Current ratios are from 200/5 to 1200/5 amps. and transformers will operate at 150% rated current continuously.

Re-designed Round-chart Recorder

Taylor Instrument Companies

WHILE this new instrument possesses several mechanical improvements, emphasis has been laid on the beauty of its design, both in itself and also to harmonize when used in panel board mounting. The new design is the work of a leading American industrial artist, working in coöperation with the companies' engineering staff. The aluminum die cast case is rust-proof, is finished in smooth lustrous black and may be had as surface mounted or flush mounted type with or without a polished flange. Other finishes are available including white enamel for milk and other food industries service. (The dairy recorders have charts giving 50% increase in effective scale length.) Mercury recorders are standard but gas or vapor systems are also available. The instruments are available as 1, 2 or 3 pen recorders for temperature or pressure, or any combination. An electric clock can be supplied instead of the standard spring wound clock, if desired. A feature of the mercury instrument is Taylor "Accuratus" tubing automatically compensating for temperature changes along its path. Lengths up to 100 ft. or more may be used. Other features include: "simplified movement; stainless steel pen and pen arm; micrometer pen adjustment; time target for setting time on time line; multiple thread retaining hub; heat-treated and aged alloy springs; accurate charts printed on highest quality paper," etc.



◆ ◆ ◆

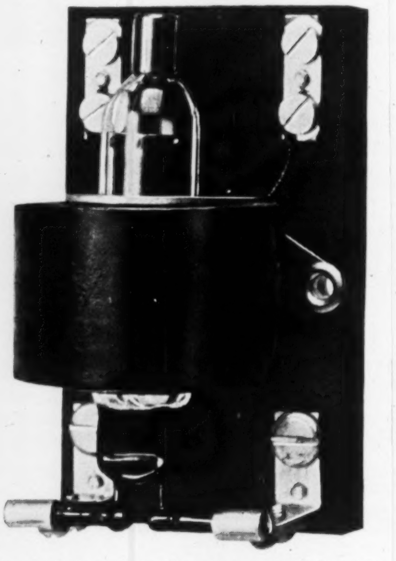
"Diamond H" Magnetrole Relay

Hart Mfg. Co.

INSIDE an especially designed glass tube is a porcelain cup separating two concentric pools of mercury, connected to terminals at the bottom of the base. Surrounding the porcelain cup is a metal cylinder which, when moved, displaces the mercury in the outer pool, completing a mercury-to-mercury contact. The action of this cylinder is controlled by a solenoid. It is entirely magnetic, the tube remaining stationary at all times.

The design of this relay and its positive action make it suitable for motor and light control, time and temperature control, signal equipment, photo-electric cell operation, sign flasher service, etc.

The "Diamond H" Magnetrole Relay requires very small operating current, 5 watts being maximum for the 10 and 20 amp. sizes. It is silent in operation and it can be used in the presence of dangerous, explosive gases. It will operate continuously up to 120 breaks per min. Mounting position is not critical as test shows that the tube will work satisfactorily if tipped 25°. The tube can be replaced easily and quickly if accidentally injured.

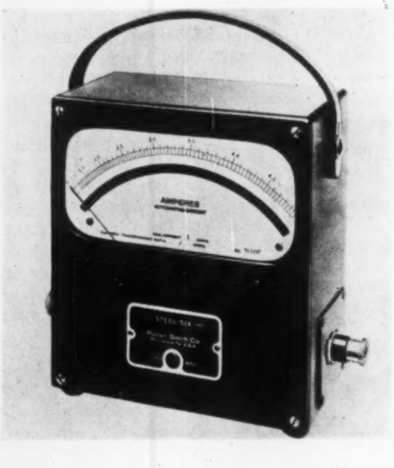


◆ ◆ ◆

Portable Electrical Instruments

Roller-Smith Co.

A NEW line of "Steel Six" portable instruments is announced. The outstanding features are said to be: rugged steel cases, approximately 6" square, which shield the mechanism against the effect of external magnetic influences; unusually long scales (5-3/16"); open and well lighted dials; and fusing when desired. The line is complete, comprising d.c. ammeters, milliameters, voltmeters, millivoltmeters and voltammeters and a.c. ammeters, milliammeters, voltmeters, single and polyphase wattmeters, frequency meters and power factor meters. Accuracy: for ammeters, voltmeters and singlephase wattmeters, limit of error 0.5% of full scale; for all other instruments 1% of full scale.



Pilot-controlled, Self-powered Water Regulating Valve

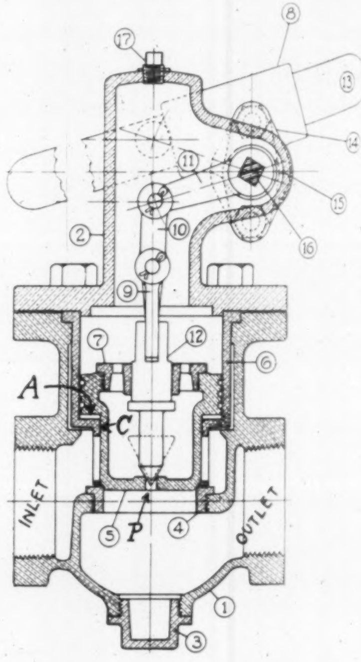
Cochrane Corp.

INSIDE the valve itself, a pilot (actuated by a float or other primary element) admits the supply pressure to a hydraulic piston which follows up and moves with the pilot, thus avoiding overtravel and hunting. Pilot and main valve, both single-seated, close with and are held tightly to seat by the pressure. No auxiliary operating fluid or electrical energy is required for operation.

A simple form of this new valve (sizes up to 2½") is illustrated. Cylinder 6 is a combined hydraulic power cylinder and seat ring. Part 5 is a combined piston and single-seated valve, the valve part of which not only covers the four V-shaped flow ports but seats tightly when in the closed position shown at which time inlet pressure and pressure *above* piston are equal.

When pilot valve 12 is lifted, pressure above piston drops to outlet pressure. Inlet pressure acts on annular area *A* to lift main valve. It cannot do it suddenly because flow to annular space must pass through clearance *C* between 5 and 6. Main valve rise continues until pilot port, *P* again approaches pilot valve. Main valve comes to rest when rate of inflow through clearances, and outflow through pilot, are equal.

Common faults of flow regulating valves have been eliminated. It is said that the new valve does away with leakage, non-uniform variation of flow with float movement, slamming or hammering, sticking due to dirt, wear or unbalanced pressures, erosion, corrosion, etc.

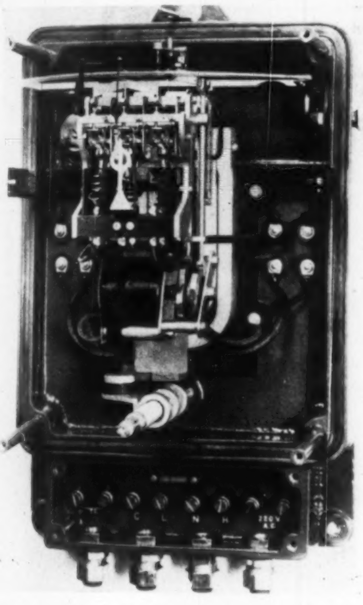


1. Body
2. Bonnet
3. Bottom Cap
4. Seat Ring
5. Piston Valve
6. Cylinder
7. Lock Nut
8. Lever Hub
9. Disk Link
10. Vertical Link
11. Internal Lever
12. Pilot Valve
13. External Operating Lever
14. Gland
15. Stuffing Box
16. Operating Shaft
17. Air Vent Plug

Pyrometer Controller Employs New Principle

Negretti & Zambra

NO work is performed by the thermal system of this new controlling and indicating instrument. Operating of all contacts is done by a synchronous motor. Mercury switches are used for opening and closing circuits. The instrument operates with resistance or thermocouple primary systems, is suitable for controlling temperatures up to 1400°C. (2550°F.) or for flashings colored lights, and is made in 3 models with 1, 2 or 3 switches. The capacity of the single-switch model is 15 amps. at 200 volts; in other models the capacity of each switch is 5 amps. at 200 volts. The movement is of the double-pivoted spring-controlled type with jeweled bearings. The scale length is 5¾". Automatic cold-junction compensation is of the bi-metallic type. The resistance system instruments are designed to operate directly off the a.c. supply, doing away with storage batteries or dry cells.



Below the indicating pointer and connected to it is a flexing pointer M, directly above which is a depressor bar in the shape of an elongated "U," operated by the cam wheels connected to the motor. Directly below the flexing pointer will be seen 3 pallets connected to the 3 switches. The instrument shown in the photograph is employed for controlling signal lamps, the central pallet—narrower than the other 2—representing the correct temperature, deviation, causing either the "high" or "low" lamps to light. The width of the pallets varies with individual requirements.

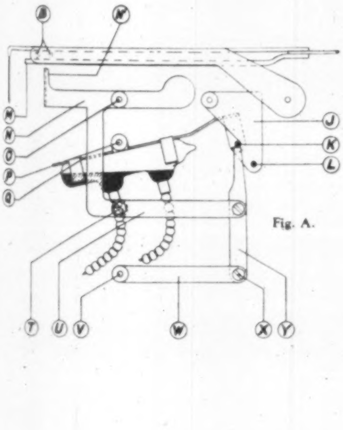


Fig. A.

The depressor drops for a period of 10 seconds every 20 seconds, and by medium of the flexing pointer, depresses the pallet over which the latter is at the time. Although the cycle of operations is completed every 20 seconds, any switch remains in the same position for any multiple of 20 seconds, until the change of temperature is such that an alteration in its position is necessary. The cycle of operation is shown in the diagrams.

In Fig. A the mercury swifch mounted on the platform Q, pivoted at P, is in the "off" position, held by gravity-controlled detent piece J, which engages with pin K on the extension switch platform Q. Detent piece J has a pin, L.

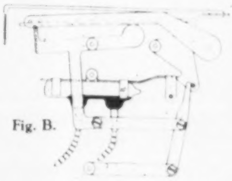


Fig. B.

When lever N, pivoted at O, is depressed by depressor bar B and flexing pointer M, striking pallet N', striker Y moves to the right, strikes L, moving the detent piece and allowing the switch carriage to fall by gravity to the "on" position. (Fig. B)

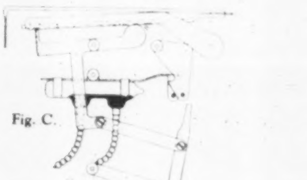


Fig. C.

When lever N is thus depressed, one of the cams on the motor, which is connected by a push-rod to links W and U, pivoted at V and T respectively, allows these to fall, causing striker to release detent piece. (Fig. C)

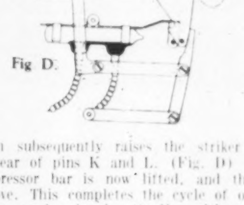


Fig D.

The cam subsequently raises the striker with its top end clear of pins K and L. (Fig. D)

The depressor bar is now lifted, and the pointer free to move. This completes the cycle of operations. The switch remains in the "on" position. Although lever N is no longer held down by flexing pointer M, it is not free, as striker Y cannot move to the left on account of detent piece J. If the temperature does not change when the depressor bar next falls, the position shown in Fig. D is regained.

If, however, the temperature alters, and the flexing pointer M moves so as to be over a different pallet, when the depressor bar next falls, lever N is not affected, and when the striker is dropped by the cam on the motor, lever N returns by gravity to a horizontal position (Fig. E). This is possible, owing to the special shape of the depressor bar, which allows N to pass through.

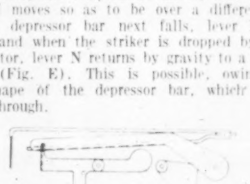


Fig. E.

On the upward motion of links U and W, the striker moves upwards, and replaces switch platform Q to the "off" position, where it is held by the detent piece, as shown in Fig. A.

There are as many strikers Y as there are mercury switches in the mechanism, and all are mounted on the same rod, joining the ends of links W and X. They thus all rise and fall together and replace the switch or not according to whether their respective levers N have been depressed.

Mercury Swing Type Relay

Struthers Dunn, Inc.

SILENT and sparkless operation is an assured characteristic of this general class of relays. The new type of relay represents also an attempt by the makers "to move the glass around the mercury rather than the mercury in the glass." The armature comes to dead center without striking core, giving full floating action at all times. The 5 standard types include single- and double-tube or -pole, normally open or closed. Housing dimensions 7⅞ x 5¾ x 3¾". Applications: for controlling loads up to 25 amps. at 110 volts a.c. or 115 volts d.c. in presence of inflammable gases or vapors.

◆ ◆ ◆

New Design of "Adjustat" Rheostat

Ward Leonard Electric Co.

THE "dead shaft" construction completely insulated from current carrying parts, simplifies single hole mounting on steel panels without the use of insulating bushings or washers.

A 2¾" circular refractory plate forms the base for the special resistance wire of low temperature coefficient of resistivity. The plate, wire, contacts and terminal connections are protected against corrosion and damage by fused-on Vitrohm (vitreous enamel). For applications where it is desired to make or break another circuit, a toggle switch can be furnished to operate at any part of the shaft travel. The "Adjustat" is regularly furnished from 1 to 25,000 ohms. It will dissipate 30 watts continuously with a temperature rise not exceeding 250° C. which is within the limits specified by Underwriters' Laboratories. 16 steps of control are provided and terminals arranged for potentiometer connection.

JOURNAL OF SCIENTIFIC INSTRUMENTS

PRODUCED BY THE INSTITUTE OF PHYSICS
With the co-operation of the National Physical Laboratory

Volume X FEBRUARY, 1933 Number 2

The English journal devoted to scientific instruments, their principles, construction and use. Essential to all up-to-date designers, makers and users of instruments.

CONTENTS OF THE FEBRUARY NUMBER

The Physical Society's Twenty-third Annual Exhibition

DISCOURSES GIVEN AT THE EXHIBITION:

Surface Tension and its Measurement.
By Allan Ferguson, D.Sc., F.Inst.P.

Cathode-Ray Oscillography.
By R. A. Watson Watt, B.Sc., A.M.I.E.E., F.Inst.P.

Time-Keeping—Old and New.
By F. Hope-Jones, M.I.E.E., F.R.A.S.

DESCRIPTIONS OF THE EXHIBITS:

Craftsmanship and Draughtsmanship Competitions for Apprentices and Learners.

The Research Section.
By F. E. J. Ockenden, A.M.I.E.E.

Apparatus and Exhibits of Educational Interest.
By D. O. Wood, F.Inst.P.

General Physical Instruments.
By J. H. Awbery, B.A., B.Sc., F.Inst.P.

Optical Instruments.
By W. B. Coutts, M.A., B.Sc., F.R.S.E., F.Inst.P.

Electrical Instruments.
By R. L. Smith-Rose, D.Sc., Ph.D., A.M.I.E.E. and R. S. J. Spilsbury, B.Sc., M.I.E.E.

The subscription price for a yearly volume is 30/– net (post-free) payable in advance; separate parts, 2/6 net each (post-free 2/8).

Subscriptions may be sent to any bookseller, or to the

CAMBRIDGE UNIVERSITY PRESS
FETTER LANE, LONDON, E.C.4

Office for Advertisements — WALTER JUDD, LTD.
47 Gresham Street, London, E.C.2

Editorial Office — INSTITUTE OF PHYSICS
1, Lowther Gardens, Exhibition Road, London, S.W.7

THE REVIEW OF SCIENTIFIC INSTRUMENTS

With

Physics News and Views

F. K. RICHTMYER, Editor

Published monthly by the American Institute of Physics in collaboration with the Optical Society of America and the Association of Scientific Apparatus Makers of America.

Includes, beginning January, 1933, Editorials and special articles on recent developments in physics; also news of interest to physicists; tables of contents of current journals.

◆

CONTENTS FOR MARCH, 1933, ISSUE
Vol. 4, No. 3

Physics Forum:
- Editorial.
- Molecular Binding.
- Maxwell's Field Equations.
- New Achievements in Transmutation.

Contributed Articles:
- High Potential Porcelain X-Ray Tube.
- Recording Infrared Quartz Spectrograph.
- Large Grazing-Incidence Vacuum Spectrograph.
- Practical Vacuum-Tube Circuit for the Measurement of Electromotive Force.
- A. Angstrom's Total Immersion Hydrometer.
- Thermel Technic.
- Relaxation Inverter and D. C. Transformer.
- High-Gain Audiofrequency Amplifier.

Abstracts.

Book Reviews.

Physics News:
- The Institute's Page.
- Notes.
- News of the Societies.
- Calendar.
- Letters to the Editor.

Current Literature of Physics.

◆

Send Subscriptions to

AMERICAN INSTITUTE of PHYSICS
11 EAST 38TH ST., NEW YORK

Annual subscription Four Dollars per year, post paid; combined Subscription with the Journal of the Optical Society of America, Six Dollars per year.

INSTRUMENTS ABSTRACTS

Abstracts on instruments and devices for measurement, inspection and control.

Humidity and Moisture (2.08)

Remote Measurement of Humidity. (Feuchtigkeitsfernmessung.) L. Scriba. *Feinmechanik und Präzision,* Vol. 40, April 1, 1932, pages 65-68.

Present methods of remote measurement of humidity by psychrometers, hygrometers, electric resistance thermometers and electric methods based on the change of resistance of hygroscopic substances are reviewed and instruments described. Ha (2.08)

Determination of the Moisture Content of Paper. (Die Wasserbestimmung in Papier.) E. H. Riesenfeld & T. Hamburger. *Der Papier-Fabrikant,* Vol. 28, April 27, 1930, pages 288-289.

The traditional methods are briefly reviewed and the writers' new extraction method with tetra-chlor-ethan is discussed. EF (2.08)

A New Moisture Meter. (Ein neuer Feuchtigkeitsmesser.) *Die Waerme,* Vol. 54, June 6, 1931, pages 445-446.

The various features of the new psychrometric moisture meter of the Siemens & Halske Co. are explained and shown in 5 illustrations. EF (2.08)

Remote Humidity Measurement. (Feuchtigkeitsfernmessung.) Ludwig Scriba. *Zeitschrift Verein Deutscher Ingenieure,* Vol. 76, Feb. 6, 1932, page 142.

At temperatures below 20° C. the humidity is measured more accurately with hygrometers, while at higher temperatures psychrometers are preferable. The readings are transmitted to a remote cross-coil moving coil instrument. Ha (2.08)

Power, Work, and Output (2.09)

The Engine Indicator—Its Design and Theory. Kalman J. DeJuhasz, *Instruments,* Vol. 5, June 1932, pages 137-142.

First monthly instalment of monograph on "Pressure (Engine) Indicators." Consists of introduction and of a brief but profusely illustrated History of the Indicator. MFB (2.09)

The Engine Indicator—Its Design and Theory. Kalman J. DeJuhasz. *Instruments,* Vol. 5, July 1932, pages 169-172.

This instalment continues the discussion of component parts, dealing specifically with: frame or body, indicating valve, cylinder and piston, piston rod, spring. 6 figs. MFB (2.09)

Physical Properties (2.10)

Comparison of Porosity Data According to Schopper with Data Obtained with the Densometer of Gurley. (Vergleich der Luftdurchlaessigkeitszahlen nach Schopper mit den Densometerwerten nach Gurley.) R. A. Krauss. *Der Papier-Fabrikant,* Vol. 29, Fest- & Auslandsheft, June 1931, pages 96-97.

The results of experiments with the Schopper Porosity Meter and the Gurley Densometer yielded a curve which correlates the data gained by both testing methods. The conversion can be accomplished by the diagram included in the paper. EF (2.10)

Strength Determination of Cellulose. (Festigkeitsbestimmungen von Zellstoffen.) K. G. Jonas. *Der Papier-Fabrikant,* Vol. 28, Nov. 30, 1930, pages 800-805.

The speaker at the Verein der Zellstoff- und Papier Chemiker und Ingenieure summarizes the latest advancements concerning the strength testing of cellulose and reports on his own testing method suggested as the basis for a reproducible standard testing method. EF (2.10)

Equipment for Determining the Melting Curves of Low Boiling Point Materials. (Vorrichtung zur Feststellung der Schmelzkurven niedrig siedender Stoffe.) J. Schmolke, *Die Waerme,* Vol. 54, Feb. 7, 1931, pages 97-99.

The paper is devoted to a description of the testing equipment developed by Simon and co-workers for melting curve determinations of Helium, Oxygen, Nitrogen, Argon and Neon. The principle involved in the apparatus is that the pressure of a high pressure tube is determined by measuring the elastic deformations of the tube. The writer reveals a method which extends the measuring range to pressures higher than 10,000 atmospheres. The results of some experiments are communicated. EF (2.10)

Testing for Strength of Paper Half-Stuffs. (Zur Festigkeitspruefung von Papierhalbstoffen.) W. Wirth. *Der Papierfabrikant,* Vol. 29, No. 31, Aug. 2, 1931, pages 524-526.

Applying the Schopper instrument, the author checked the results of Humm gained on his newly invented testing apparatus. Strength values determined by both testing machines disagree. EF (2.10)

The Calculation of the Critical Viscosity and the Validity of the Stokes Law with Reference to the Tausz Ball-Drop-Viscosimeter. (Ueber die Berechnung der kritischen Viskositaet und die Gueltigkeit des Strokesschen Gesetzes im Tauszschen Kugelfallviskosimeter.) A. Rabl & F. Geiger. *Petroleum,* Vol. 24, June 10, 1931, pages 439-442.

Mathematical derivations yield following conclusions: The knowledge of the multiplication coefficient of 4.5 and the lower limit of application (critical viscosity) are sufficient to the utilization of the Standard Trausz Ball Drop Viscosimeter, built by the R. Jung A.G. The writers show how to find these characteristic figures if balls other than steel are employed. EF (2.10)

The Flash-Point Tester of Schluetter. (Der Flammpunktspruefer von Schlueter.) W. Bleyberg. *Petroleum,* Vol. 24, June 10, 1931, page 8.

A brief reference. EF (2.10)

FEWER REJECTS
LESS SPOILAGE

when his WESTON *says:*

"The lighting is OK"

Improper lighting and poor work go hand-in-hand. Avoid them! You can do it now with ease. No experience is necessary. When the Weston Foot-Candle Meter, Model 614 is used.

This self-contained, pocket sized meter measures foot candles directly. No batteries or lamps are needed. You get the answer on the dial without a single calculation. And there is nothing to wear out or replace.

You will find the Weston Foot-Candle Meter one of the most effective and inexpensive tools for increasing efficiency and banishing waste. Write for Booklet M-1. It tells the whole story.

Weston Electrical Instrument Corp.,
591 Frelinghuysen Ave., Newark, N. J.

WESTON
Instruments

INSTRUMENTS INDEX

Of instruments and devices for measurement, inspection or control

If you are unable to find what you require in this section of INSTRUMENTS—write Information Section, Instruments Publishing Company. Give complete information of requirements.

ACOUSTIMETERS
- Burgess Labs., Inc., C. F.
- General Electric Co.
- General Radio Co.

ADJUSTABLE ORIFICE
- Bailey Meter Co.

AIR FLOW INDICATORS
- Bailey Meter Co.
- Brown Instrument Co.
- Defender Autom'c Reg. Co.
- Foxboro Co.
- Morey & Jones, Ltd.
- Taylor Instrument Cos.

AIR METERS
- Bailey Meter Co.
- Bristol Co.
- Brown Instrument Co.
- Defender Autom'c Reg. Co.
- Foxboro Co.
- Taylor Instrument Cos.

ALTIMETERS
- General Electric Co.
- Taylor Instrument Cos.

ALTITUDE BAROMETER
- Taylor Instrument Cos.

AMMETERS—Indicating
- General Electric Co.
- General Radio Co.
- Rawson Elec. Inst. Co.
- Weston Elec. Inst., Corp.

Recording
- Bristol Company
- Brown Instrument Co.
- Esterline-Angus Co.
- General Electric Co.

ANEMOMETERS
- Bristol Company
- Esterline-Angus Co.
- Taylor Instrument Cos.

ASPHALT TESTING APPARATUS
- Taylor Instrument Cos.

ASTRONOMICAL INSTRUMENTS
- Gaertner Scientific Corp.

ATTENUATION NETWORKS
- General Radio Company
- Rubicon Company
- Ward Leonard Elec. Co.

AUDIO-FREQUENCY OSCILLATORS
- General Radio Company

BALANCING MACHINES
- General Electric Co.
- Baldwin-Southwark Corp.

BAROMETERS—Aneroid, Mercurial, Recording
- Bristol Company
- Defender Autom'c Reg. Co.
- Gaertner Scientific Corp.
- Taylor Instrument Cos.

BATTERY CHARGING RHEOSTATS
- Rubicon Company
- Ward Leonard Elec. Co.

BATTERY TESTERS
- Weston Elec. Inst., Corp.

BEARING TESTERS
- Burgess Labs., Inc., C. F.

BOARDS: INSTRUMENT
- Bailey Meter Co.
- Bristol Co.
- Brown Instrument Co.
- Foxboro Co.

BOILER METER
- Bailey Meter Co.

BRAKE TESTING METERS
- Rawson Elec. Inst. Co.

BRIDGES, ELECTRICAL

Capacity, Inductance, Kelvin Resistance, Temperature, Wheatstone, Percent
- Eppley Laboratory, Inc.
- General Electric Co.
- General Radio Co.
- Rubicon Company

Reactance
- Rubicon Company

CABLE TESTERS
- Rawson Elec. Inst. Co.
- Rubicon Company

CALORIMETERS

Peroxide, Oxygen Bomb
- Gaertner Scientific Co.

CAPACITANCE METERS
- General Electric Co.
- General Radio Co.
- Rubicon Company
- Weston Elec. Inst. Corp.

CARBON DIOXIDE METERS
- Brown Instrument Co.
- Foxboro Co.

CATHETOMETERS
- Gaertner Scientific Corp.

CHLORINE GAS FLOW INDICATORS
- Morey & Jones, Ltd.

CHRONOGRAPHS AND CHRONOMETERS
- Esterline-Angus Co.
- Gaertner Scientific Corp.
- General Electric Co.
- General Radio Co.

CLINOMETER
- Baldwin-Southwark Corp.

CLOCKS—Gage Board
- Brown Instrument Co.
- Bristol Company
- Defender Autom'c Reg. Co.
- Esterline-Angus Co.
- Foxboro Co.

COILS

Resistance, Inductance, Special
- General Electric Co.
- General Radio Co.
- Rubicon Company
- Ward Leonard Elec. Co.

COIL TESTING EQUIPMENTS
- General Electric Co.
- Rubicon Company

COLORIMETERS
- Bausch & Lomb Optical Co.
- General Electric Co.
- Hellige, Inc.

COMBUSTION CONTROL EQUIPMENT
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Defender Autom'c Reg. Co.
- Morey & Jones, Ltd.

COMMUNICATION MEASURING INSTRUMENTS
- Esterline-Angus Co.
- General Radio Company
- Rawson Elec. Inst. Co.

COMPARATORS
- Bausch & Lomb Optical Co.
- Gaertner Scientific Corp.
- General Electric Co.

COMPASS
- Taylor Instrument Cos.

CONDENSERS—Electrical
- General Electric Co.
- General Radio Co.
- Rubicon Company

CONDUCTIVITY METERS

Indicating, Recording, Controlling
- Esterline-Angus Co.
- Rawson Elec. Inst. Co.
- Rubicon Company

CONTOUR MEASURING PROJECTOR
- Bausch & Lomb Optical Co.

CONTROLS, AUTOMATIC

Combustion
- Bailey Meter Co.
- Defender Autom'c Reg. Co.
- Morey & Jones, Ltd.

Condensation
- Bristol Company
- Taylor Instrument Cos.

Damper
- Bristol Company
- Brown Instrument Co.
- Defender Autom'c Reg. Co.
- Foxboro Co.
- Morey & Jones, Ltd.
- Taylor Instrument Cos.

Demand Pressure
- Bailey Meter Co.
- Foxboro Co.

Feed Water
- Bailey Meter Co.
- Bristol Co.
- Brown Instrument Co.
- Foxboro Co.

Filter Rate
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.

Flow
- Bailey Meter Co.
- Brown Instrument Co.
- Foxboro Co.

Gravity
- Bailey Meter Co.

Humidity
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

Humidity & Temperature
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

Liquid Level
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.

Materials Testing, Strain-Time
- Baldwin-Southwark Corp.

Materials Testing, Stress-Time
- Baldwin-Southwark Corp.

Materials Testing, Load Maintenance
- Baldwin-Southwark Corp.

Pressure & Vacuum
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

Pyrometer
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Defender Autom'c Reg. Co.
- Foxboro Co.
- Taylor Instrument Cos.

Rate-Volume
- Foxboro Co.

Refrigeration
- Bristol Company
- Brown Instrument Co.
- Taylor Instrument Cos.

Special
- Rubicon Co.

Tachometer
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Weston Elec. Inst. Corp.

Temperature-Time
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

Thermometer
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Defender Autom'c Reg. Co.
- Foxboro Co.
- Taylor Instrument Cos.

Thermostat
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

Time
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

Vacuum
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

Valve—Motor Operated
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

Voltage A.C.
- Ward Leonard Elec. Co.

Water Level
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

COUNTERS—Ratchet, Magnetic
- Esterline-Angus Co.
- Veeder-Root, Inc.

Revolution
- Baldwin-Southwark Corp.
- Bristol Company
- Brown Instrument Co.
- Veeder-Root, Inc.

Stroke
- Baldwin-Southwark Corp.
- Bristol Company
- Veeder-Root, Inc.

CREEP TESTER
- Baldwin-Southwark Corp.

CURRENT RECORDERS
- Bristol Company
- Esterline-Angus Co.
- General Electric Co.

CYCLE CONTROLLERS
- Bristol Co.

CYCLE COUNTERS
- General Radio Co.

CYCLOMETERS
- Veeder-Root, Inc.

DAMPING TESTER
- Baldwin-Southwark Corp.

DEFORMETER (Beggs)
- Baldwin-Southwark Corp.

DEMAND METERS

Gas
- Foxboro Co.

Electric: Indicating, Recording, Printing
- General Electric Co.

DIVIDING HEAD

Optical
- Bausch & Lomb Optical Co.

DIVIDING MACHINES
- Gaertner Scientific Corp.

DRAFT GAGES—See Gages

DYNAMOMETERS
- General Electric Co.
- Rawson Elec. Inst. Co.
- Weston Elec. Inst. Corp.

EARTH CURRENT METERS
- Rawson Elec. Inst. Co.

ELECTRIC TELEMETERS
- Baldwin-Southwark Corp.
- Esterline-Angus Co.
- General Electric Co.

ELECTRIC WAVE FILTER SECTIONS
- General Radio Company

ELECTROMETERS
- Rubicon Co.

ELECTRONIC METERS
- Esterline-Angus Co.
- General Electric Co.
- General Radio Co.
- Rawson Elec. Inst. Co.

ENGINE INDICATORS
- Baldwin-Southwark Corp.

ENGINE REVOLUTION COUNTERS
- Veeder-Root, Inc.

EXTENSOMETER
- Baldwin-Southwark Corp.

FATIGUE TESTERS
- Baldwin-Southwark Corp.

FAULT FINDERS
- Rubicon Company
- Weston Elec. Inst. Corp.

FIELD RHEOSTATS
- Ward Leonard Elec. Co.

FLASH & BURNING POINT TESTERS
- Taylor Instrument Cos.

FLOW METERS

Indicating
- Bailey Meter Co.
- Brown Instrument Co.
- Defender Autom'c Reg. Co.
- Morey & Jones, Ltd.

Indicating & Recording
- Bailey Meter Co.
- Brown Instrument Co.
- Foxboro Co.

Intergrating & Recroding
- Morey & Jones, Ltd.

FLUE GAS ANALYZERS
- Brown Instrument Co.

FLUXMETERS
- Rawson Elec. Inst. Co.
- Rubicon Company

FREQUENCY METERS

Indicating
- General Electric Co.
- Weston Elec. Inst. Corp.

Recording
- Bristol Company
- Esterline-Angus Co.
- General Electric Co.

Standards
- General Radio Co.

FUEL FLOW INDICATORS
- Morey & Jones, Ltd.

FURNACE CONTROLS
- Bailey Meter Co.
- Bristol Company
- Defender Autom'c Reg. Co.
- Taylor Instrument Cos.

FUSES

Instrument
- Littelfuse Laboratories

GAGES

Absolute Pressure
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

Amplifying

Comparator

Cylinder

Deformation
- Baldwin-Southwark Corp.

Dial

Differential Pressure
- Bailey Meter Co.
- Brown Instrument Co.
- Foxboro Co.
- Morey & Jones, Ltd.

Draft
- Taylor Instrument Cos.
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

Drill
- Bausch & Lomb Optical Co.

Filter Rate
- Morey & Jones, Ltd.

Flow
- Bailey Meter Co.
- Brown Instrument Co.
- Morey & Jones, Ltd.

Liquid Level
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Esterline-Angus Co.
- Foxboro Co.
- Morey & Jones, Ltd.
- Taylor Instrument Cos.

Loss of Head
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Morey & Jones, Ltd.

Pitch Diameter

Pressure
- Bailey Meter Co.
- Baldwin Southwark Corp.
- Bristol Company
- Brown Instrument Co.
- Esterline-Angus Co.
- Foxboro Co.
- Taylor Instrument Cos.

Pressure-Temperature
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Esterline-Angus Co.
- Foxboro Co.
- Taylor Instrument Cos.

Pressure & Vacuum
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Esterline-Angus Co.
- Foxboro Co.
- Taylor Instrument Cos.

Profile
- Bausch & Lomb Optical Co.

Rain
- Esterline-Angus Co.
- Taylor Instrument Cos.

Recording—Distance
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Esterline-Angus Co.
- Taylor Instrument Cos.

Strain
- Baldwin-Southwark Corp.
- General Electric Co.

Tester
- Baldwin-Southwark Corp.

Thickness
- Esterline-Angus Co.

Vacuum
- Esterline-Angus Co.
- General Electric Co.
- Taylor Instrument Cos.

Volume
- Brown Instrument Co.
- Foxboro Co.

Water Level for Boilers
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.

Wind
- Bristol Company
- Brown Instrument Co.
- Esterline-Angus Co.

GALVANOMETERS
- Brown Instrument Co.
- General Radio Co.
- Rawson Elec. Inst. Co.
- Rubicon Company
- Taylor Instrument Cos.
- Weston Elec. Inst. Corp.

GAS ANALYTICAL METERS

Electrical
- Brown Instrument Co.

GAS FLOW INDICATORS
- Morey & Jones, Ltd.

GAS LEAK INDICATORS
- Taylor Instrument Cos.

GAS-METERS
- Bailey Meter Co.
- Brown Instrument Co.
- Foxboro Co.

GOVERNORS

Pressure
- Bailey Meter Co.
- Bristol Company
- Brown Instrument Co.
- Taylor Instrument Cos.

Pump
- Bailey Meter Co.
- Taylor Instrument Cos.

Water Wheel
- Baldwin-Southwark Corp.

GROUND DETECTORS
- Rubicon Company
- Weston Elec. Inst. Corp.

HAND TALLEYS
- Veeder-Root, Inc.

HARDNESS TESTERS
- Baldwin-Southwark Corp.

HELIOSTATS
- Gaertner Scientific Corp.

HIGH FREQUENCY APPARATUS
- Rawson Elec. Inst. Co.
- Rubicon Company
- Weston Elec. Inst. Corp.

HIGH VOLTAGE

Fuses
- Littelfuse Laboratories

Indicators
- Weston Elec. Inst. Corp.

Measuring Devices
- General Electric Co.
- Weston Elec. Inst. Corp.

Testing Devices
- General Electric Co.

HUB ODOMETERS
- Veeder-Root, Inc.

HUMIDITY CONTROLLERS
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

HUMIDITY RECORDERS

Wet & Dry Bulb Thermometers
- Bristol Company
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

HYDROGEN ION TESTING APPARATUS
- Hellige, Inc.

HYDROGEN ION METERS

Indicating
- Hellige, Inc.
- Rubicon Company

HYDROMETERS
- Taylor Instrument Cos.

HYGROMETERS
- Brown Instrument Co.
- Foxboro Co.
- Taylor Instrument Cos.

ILLUMINOMETERS
- Weston Elec. Inst. Co.

INDICATORS—See Gages

INDUCTANCES
- General Radio Co.
- Rubicon Company

INSTRUMENT CALIBRATION AND REPAIRS
- Esterline-Angus Co.
- Rawson Elec. Inst. Co.
- Rubicon Company
- Weston Elec. Inst. Corp.

INSTRUMENT FUSES
- Littelfuse Laboratories

INSTRUMENT TRANSFORMERS
- Esterline-Angus Co.
- General Electric Co.
- Weston Elec. Inst. Corp.

Split Core
- Rubicon Company

Phase Shifting
- Rubicon Company

INSULATION TESTING EQUIPMENT
- General Electric Co.
- Rubicon Company

INTERFEROMETERS
- Gaertner Scientific Corp.

KEYS AND SWITCHES
- General Radio Co.
- Rubicon Company

KEYSTROKE COUNTERS (for Typewriters, etc.)
- Veeder-Root, Inc.

LABORATORY RHEOSTATS
- Rubicon Company
- Ward Leonard Elec. Co.

LACTOMETERS
- Taylor Instrument Cos.

LENGTH MEASURING MACHINES
- Gaertner Scientific Corp.

LEVELS

Centering
- Bausch & Lomb Optical Co.

Engineer's, Wye, Precision Prism
- Taylor Instrument Cos.

LOCOMOTIVE INDICATORS
- Baldwin-Southwark Corp.

MAGNETIC RELAYS
- Ward Leonard Elec. Co.

MAGNETOMETERS
- Rubicon Company

MANOMETERS
- Bailey Meter Co.
- Bristol Co.
- Brown Instrument Co.
- Defender Autom'c Reg. Co.
- Foxboro Co.
- Morey & Jones, Ltd.

MASTER CLOCKS
- Gaertner Scientific Corp.
- General Electric Co.

MEGOHMMETERS
- Rubicon Company

MEGOHM VOLTMETERS
- Weston Elec. Inst. Corp.

MICROAMMETERS
- General Electric Co.
- Esterline-Angus Co.
- General Electric Co.
- Rawson Elec. Instru. Co.
- Weston Elec. Inst. Corp.

MICROFARADMETERS
- General Radio Co.
- Rubicon Company
- Weston Elec. Inst. Corp.

MICROMETERS
- Gaertner Scientific Corp.

MICROMETER SLIDES
- Gaertner Scientific Corp.

MICROSCOPES

Brinell
- Bausch & Lomb Optical Co.
- Gaertner Scientific Corp.

Measuring
- Gaertner Scientific Corp.

Metallographic
- Bausch & Lomb Optical Co.

Petrographical
- Bausch & Lomb Optical Co.

Toolmakers'
- Bausch & Lomb Optical Co.
- Gaertner Scientific Corp.

MICROTOMES
- Bausch & Lomb Optical Co.

MILLIAMMETERS
- Bristol Company
- Esterline-Angus Co.
- General Electric Co.
- General Radio Co.
- Rawson Elec. Inst. Co.
- Weston Elec. Inst. Corp.

MILLIVOLTMETERS
- Bristol Company
- Brown Instrument Co.
- Esterline-Angus Co.
- General Electric Co.
- Rawson Elec. Inst. Co.
- Taylor Instrument Cos.
- Weston Elec. Inst. Corp.

MIRRORS
- Hellige, Inc.

MODULATION METERS
- Esterline-Angus Co.
- General Radio Co.
- Weston Elec. Inst. Corp.

MOISTURE METERS
- General Radio Co.

MOTION RECORDERS

Mechanical
- Baldwin-Southwark Corp.
- Bristol Company
- Esterline-Angus Co.
- Foxboro Co.

- **MOTOR STARTERS**
  - Ward Leonard Elec. Co.
- **MULTIMETERS**
  - Rawson Elec. Inst. Co.
- **MULTIPLE PEN RECORDERS**
  - Baldwin-Southwark Corp.
  - Bristol Co.
  - Esterline-Angus Co.
  - Foxboro Co.
- **MULTIPLIERS**
  - General Electric Co.
  - Weston Elec. Inst. Corp.
- **NICKEL SOLUTION TESTERS**
  - Hellige, Inc.
- **NOISE MEASURING SETS**
  - General Radio Co.
- **OHM METERS**
  - Esterline-Angus Co.
  - General Electric Co.
  - Rawson Elec. Inst. Co.
  - Rubicon Company
  - Weston Elec. Inst. Corp.
- **OIL TESTING APPARATUS**
  - General Electric Co.
  - Taylor Instrument Cos.
- **OPERATION RECORDERS**
  - **Electrical**
    - Bristol Company
    - Brown Instrument Co.
    - Esterline-Angus Co.
    - Foxboro Co.
    - Taylor Instrument Cos.
- **OPTICAL PARTS**
  - **Lenses, Prisms, Test Planes**
    - Gaertner Scientific Corp.
- **ORIFICE METERS**
  - **Indicating & Recording**
    - Bailey Meter Co.
    - Brown Instrument Co.
    - Defender Autom'c Reg. Co.
    - Foxboro Co.
    - Morey & Jones, Ltd.
- **OSCILLATORS**
  - Weston Elec. Inst. Corp.
- **OSCILLOGRAPHS**
  - Baldwin-Southwark Corp.
  - General Electric Co.
  - General Radio Co.
  - Hellige, Inc.
  - **Automatic**
    - General Electric Co.
  - **Cathode Ray**
    - General Electric Co.
- **PANTOGRAPHS**
  - Gaertner Scientific Corp.
- **PERISCOPES**
  - Bausch & Lomb Optical Co.
  - Gaertner Scientific Corp.
- **PERMEAMETERS**
  - General Electric Co.
  - Rubicon Company
- **PHOTO-ELECTRIC CELLS**
  - General Electric Co.
  - Weston Elec. Inst. Corp.
- **PHOTO-ELECTRIC COLOR ANALYZERS**
  - General Electric Co.
- **PHOTO-ELECTRIC COLOR COMPARATORS**
  - General Electric Co.
- **PHOTOMETERS**
  - Gaertner Scientific Corp.
  - Bausch & Lomb Optical Co.
- **PHOTO-MICROGRAPHIC EQUIPMENT**
  - Rawson Elec. Instru. Co.
- **PHYSICAL TESTING MACHINES**
  - Baldwin-Southwark Corp.
- **PITOT TUBE METERS**
  - Brown Instrument Co.
  - Defender Autom'c Reg. Co.
  - Foxboro Co.
  - Morey & Jones, Ltd.
- **PLANIMETERS**
  - **Automatic Flow Record**
    - Brown Instrument Co.
    - Foxboro Co.
  - **Linear**
    - Brown Instrument Co.
    - Baldwin-Southwark Corp.
  - **Radial**
    - Bailey Meter Co.
    - Bristol Company
    - Foxboro Co.
  - **Square Root**
    - Foxboro Co.
- **POLARISCOPES**
  - Bausch & Lomb Optical Co.
  - Gaertner Scientific Corp.
  - Hellige, Inc.
- **POSITION RECORDERS**
  - Brown Instrument Co.
  - Bristol Company
  - Esterline-Angus Co.
  - Foxboro Co.
  - Taylor Instrument Cos.
- **POTENTIOMETERS—**
  - **Indicating**
    - Brown Instrument Co.
    - General Electric Co.
    - Hellige, Inc.
    - Rubicon Company
  - **Recording & Controlling**
    - Brown Instrument Co.
  - **Standard Cell Comparing**
    - Eppley Laboratory, Inc.
  - **Feussner Type**
    - Eppley Laboratory, Inc.
- **POWER FACTOR METERS**
  - Esterline-Angus Co.
  - General Electric Co.
  - Weston Elec. Inst. Corp.
- **PRESSURE RECORDERS**
  - Bailey Meter Co.
  - Baldwin-Southwark Corp.
  - Bristol Company
  - Brown Instrument Co.
  - Defender Autom'c Reg. Co.
  - Esterline-Angus Co.
  - Foxboro Co.
  - Taylor Instrument Cos.
- **PRISMS**
  - Gaertner Scientific Corp.
  - Hellige, Inc.
- **PROCESS TIMING & SIGNALING INSTRUMENTS**
  - Bristol Company
  - Brown Instrument Co.
  - Esterline-Angus Co.
  - Foxboro Co.
  - Taylor Instrument Cos.
- **PROTRACTOR**
  - **Optical**
    - Bausch & Lomb Optical Co.
- **PSYCHROMETERS**
  - **Recording**
    - Bristol Company
    - Brown Instrument Co.
    - Foxboro Co.
    - Taylor Instrument Cos.
  - **Sling**
    - Taylor Instrument Cos.
- **PYRHELIOMETERS—**
  - **Weather Bureau Type**
    - Eppley Laboratory, Inc.
- **PYROMETERS**
  - **Optical**
  - **Radiation**
    - **Indicating**
      - Brown Instrument Co.
      - Taylor Instrument Cos.
    - **Recording**
      - Brown Instrument Co.
      - Taylor Instrument Cos.
  - **Thermo-electric**
    - **Immersion**
      - Bristol Company
      - Brown Instrument Co.
      - Foxboro Co.
      - Taylor Instrument Cos.
    - **Indicating**
      - Bristol Company
      - Brown Instrument Co.
      - Defender Autom'c Reg. Co.
      - Foxboro Co.
      - Taylor Instrument Cos.
      - Bristol Company
      - Brown Instrument Co.
    - **Recording and Controlling**
      - Foxboro Co.
      - Taylor Instrument Cos.
    - **Surface Contact**
      - Bristol Company
      - Brown Instrument Co.
      - Taylor Instrument Cos.
- **RADIO FREQUENCY OSCILLATORS**
  - General Radio Company
- **RADIO SET ANALYZERS**
  - Weston Elec. Inst. Corp.
- **RADIO TEST PANEL**
  - Rubicon Company
  - Weston Elec. Inst. Corp.
- **RADIO TUBE CHECKERS**
  - General Radio Company
  - Weston Elec. Inst. Corp.
- **REFRACTOMETERS**
  - Bausch & Lomb Optical Co.
- **REGULATORS—See Controls**
- **RELAYS**
  - General Electric Co.
  - General Radio Co.
  - Ward Leonard Elec. Co.
  - Weston Elec. Inst. Corp.
  - **Light Sensitive**
    - Burgess Labs., Inc., C. F.
    - Weston Elec. Inst. Corp.
  - **Vacuum Contact**
    - Burgess Labs., Inc., C. F.
  - **Vacuum Tube**
    - Burgess Labs., Inc., C. F.
- **REMOTE METERING EQUIPMENT**
  - Bailey Meter Co.
  - Bristol Company
  - Brown Instrument Co.
  - Esterline-Angus Co.
  - General Electric Co.
  - Morey & Jones, Ltd.
- **RESISTANCE—Electrical**
  - General Radio Co.
  - Rubicon Company
  - Ward Leonard Elec. Co.
- **RESISTANCE COILS**
  - Ward Leonard Elec. Co.
- **RESISTOR UNITS**
  - Ward Leonard Elec. Co.
- **RHEOSTATS**
  - General Radio Company
  - Rubicon Company
  - Ward Leonard Elec. Co.
- **SACCHARIMETERS**
  - Bausch & Lomb Optical Co.
  - Taylor Instrument Cos.
- **SALINITY INDICATORS**
  - Esterline-Angus Co.
  - Rubicon Company
- **SCALES**
  - Gaertner Scientific Corp.
- **SEISMOGRAPHS**
- **SELSYN EQUIPMENT**
  - General Electric Co.
- **SHUNT METERS**
  - Bristol Company
  - Esterline-Angus Co.
- **SHUNTS**
  - Esterline-Angus Co.
  - General Electric Co.
  - Rawson Elec. Inst. Co.
  - Rubicon Company
  - Weston Elec. Inst. Corp.
- **SIGNALING DEVICES—Automatic**
  - Bristol Co.
  - Brown Instrument Co.
  - Foxboro Co.
  - Rubicon Company
- **SPECIAL COILS**
  - Ward Leonard Elec. Co.
- **SPECIAL ELECTRICAL INSTRUMENTS**
  - Bristol Company
  - Brown Instrument Co.
  - Esterline-Angus Co.
  - General Electric Co.
  - General Radio Co.
  - Morey & Jones, Ltd.
  - Rawson Elec. Inst. Co.
  - Rubicon Company
  - Weston Elec. Inst. Corp.
- **SPECIAL INSTRUMENTS**
  - Burgess Labs., Inc., C. F.
  - Esterline-Angus Co.
- **SPECTROGRAPHS**
  - Bausch & Lomb Optical Co.
  - Gaertner Scientific Corp.
- **SPECTROMETERS**
  - Gaertner Scientific Corp.
- **SPECTROPHOTOMETERS**
  - Bausch & Lomb Optical Co.
  - Gaertner Scientific Corp.
- **SPECTROSCOPES**
  - Bausch & Lomb Optical Co.
  - Gaertner Scientific Corp.
  - Hellige, Inc.
- **SPEED COUNTERS**
  - Veeder-Root, Inc.
- **SPEED INDICATORS**
  - **See Tachometers**
- **SPEED RECORDERS**
  - Bristol Company
  - Brown Instrument Co.
  - Esterline-Angus Co.
- **SPEED REGULATORS**
  - Ward Leonard Elec. Co.
- **STANDARD CELLS**
  - Eppley Laboratory, Inc.
  - Weston Elec. Inst. Corp.
- **STOP WATCHES**
- **STRAIN GAGES**
  - Baldwin-Southwark Corp.
  - General Electric Co.
- **SULPHUR DETERMINATION APPARATUS**
  - Burgess Labs., Inc., C. F.
- **SUNSHINE RECORDERS**
  - Taylor Instrument Cos.
- **SURGE INDICATORS & RECORDERS**
  - Esterline-Angus Co.
  - General Electric Co.
- **SYNCHRONOSCOPES**
  - Weston Elec. Inst. Corp.
- **SYNCHRONIZATION FORKS**
  - **Electrical**
    - General Radio Co.
- **TACHOGRAPH**
  - Baldwin-Southwark Corp.
- **TACHOMETERS**
  - Bailey Meter Co.
  - Bristol Company
  - Brown Instrument Co.
  - Esterline-Angus Co.
  - Foxboro Co.
  - Veeder-Root, Inc.
  - Weston Elec. Inst. Corp.
- **TACHOSCOPES**
  - Brown Instrument Co.
- **TELEMETER**
  - Baldwin-Southwark Corp.
  - Esterline-Angus Co.
- **TELESCOPES**
  - Bausch & Lomb Optical Co.
  - Gaertner Scientific Corp.
- **TENSOMETER (Huggenberger)**
  - Baldwin-Southwark Corp.
- **TESTING MACHINES**
  - **Fatigue**
    - Baldwin-Southwark Corp.
  - **Impact**
    - Baldwin-Southwark Corp.
  - **Hardness**
    - Baldwin-Southwark Corp.
  - **Portable—Tensile—Compression**
    - Baldwin-Southwark Corp.
  - **Sheet Metal**
    - Baldwin-Southwark Corp.
  - **Oil & Bearing**
    - Baldwin-Southwark Corp.
  - **Universal**
    - Baldwin-Southwark Corp.
- **THERMIONIC RECTIFIERS**
  - General Electric Co.
- **THERMO-JUNCTIONS (Electric)**
  - General Radio Co.
  - Rawson Elec. Inst. Co.
- **THERMO-VOLTMETERS & AMMETERS**
  - General Radio Company
  - Rawson Elec. Inst. Co.
  - Weston Elec. Inst. Corp.
- **THERMOPILE—Coblentz Type**
  - Eppley Laboratory, Inc.
- **THERMOMETERS**
  - **Gas Filled**
    - Bailey Meter Co.
    - Bristol Company
    - Brown Instrument Co.
    - Defender Autom'c Reg. Co.
    - Foxboro Co.
    - Taylor Inst. Companies
  - **Mechanical**
    - Brown Instrument Co.
    - Defender Autom'c Reg. Co.
    - Foxboro Co.
  - **Mercurial**
    - Bristol Company
    - Taylor Instrument Cos.
  - **Resistance**
    - Brown Instrument Co.
    - Foxboro Co.
  - **Vapor-Tension**
    - Bristol Company
    - Brown Instrument Co.
    - Defender Autom'c Reg. Co.
    - Foxboro Co.
    - Taylor Inst. Companies
  - **Wet & Dry Bulb**
    - Bristol Company
    - Brown Instrument Co.
    - Foxboro Co.
    - Taylor Instrument Cos.
- **THERMOSTATS**
  - Bristol Company
  - Brown Instrument Co.
  - Foxboro Co.
  - Taylor Instrument Cos.
- **TIME INDICATORS**
  - Baldwin-Southwark Corp.
- **TIME METERS**
  - General Electric Co.
- **TIME OPERATION RECORDERS**
  - Bristol Company
  - Esterline-Angus Co.
  - Foxboro Co.
- **TIME RECORDERS**
  - Bristol Company
  - Brown Instrument Co.
  - Esterline-Angus Co.
  - Gaertner Scientific Corp.
  - Foxboro Co.
- **TIME SWITCHES**
  - General Electric Co.
- **TIMERS**
  - Rawson Elec. Inst. Co.
  - Rubicon Company
- **TIMING DEVICES**
  - General Electric Co.
- **TORSIOGRAPH**
  - Baldwin-Southwark Corp.
- **TOTALIZING INSTRUMENTS**
  - General Electric Co.
- **TOTALIZING RELAYS**
  - **Electric**
    - General Electric Co.
- **TRANSFORMATION POINT RECORDERS**
  - Brown Instrument Co.
- **TRANSFORMERS (Instrument)**
  - Esterline-Angus Co.
  - General Electric Co.
  - General Radio Co.
  - Weston Elec. Inst., Corp.
- **TRANSITS**
  - **Astronomical**
    - Gaertner Scientific Corp.
  - **Pocket**
    - Taylor Instrument Cos.
- **TUNING FORKS—**
  - **Electrically Driven**
    - General Electric Co.
    - General Radio Co.
    - Gaertner Scientific Corp.
    - Rubicon Company
- **TURBIDITY METERS**
  - Hellige, Inc.
- **U-TUBE MANOMETERS**
  - Bailey Meter Co.
  - Brown Instrument Co.
  - Defender Autom'c Reg. Co.
  - Morey & Jones, Ltd.
  - Taylor Instrument Cos.
- **VACUUM RECORDERS**
  - Bailey Meter Co.
  - Bristol Company
  - Brown Instrument Co.
  - Defender Autom'c Reg. Co.
  - Esterline-Angus Co.
  - Foxboro Co.
  - Taylor Instrument Cos.
- **VACUUM TUBE BRIDGES**
  - General Radio Company
- **VACUUM TUBE RELAYS**
  - Burgess Labs., Inc., C. F.
- **VACUUM TUBE VOLTMETERS**
  - General Electric Co.
  - General Radio Co.
  - Rawson Elec. Inst. Co.
- **VALVES**
  - **Automatic Shut-Off**
    - Bristol Company
    - Brown Instrument Co.
    - Defender Autom'c Reg. Co.
    - Foxboro Co.
    - Taylor Instrument Cos.
  - **Balanced**
    - Bailey Meter Co.
    - Baldwin-Southwark Corp.
    - Brown Instrument Co.
    - Defender Autom'c Reg. Co.
    - Foxboro Co.
    - Taylor Instrument Cos.
  - **Diaphragm**
    - Bristol Company
    - Defender Autom'c Reg. Co.
    - Foxboro Co.
    - Taylor Instrument Cos.
  - **Electrically Operated**
    - Baldwin-Southwark Corp.
    - Bristol Company
    - Brown Instrument Co.
    - General Electric Co.
    - Taylor Instrument Cos.
  - **Motor Operated**
    - Baldwin-Southwark Corp.
    - Bristol Co.
  - **Reducing**
    - Bailey Meter Co.
    - Taylor Instrument Cos.
  - **Regulating**
    - Bailey Meter Co.
    - Bristol Co.
    - Brown Instrument Co.
    - Defender Autom'c Reg. Co.
    - Foxboro Co.
    - Taylor Instrument Cos.
- **VENTURI METERS**
  - Bailey Meter Co.
  - Brown Instrument Co.
  - Foxboro Co.
  - Morey & Jones, Ltd.
- **VIBROGRAPH**
  - Baldwin-Southwark Corp.
- **VIBROSCOPE**
  - Baldwin-Southwark Corp.
- **VISCOSIMETERS**
  - Taylor Inst. Companies
- **VOLTAGE DIVIDERS**
  - General Radio Co.
  - Rubicon Company
  - Ward Leonard Elec. Co.
- **VOLT-AMMETERS**
  - Esterline-Angus Co.
  - General Electric Co.
  - Weston Elec. Inst. Corp.
- **VOLTMETERS**
  - **Electrostatic**
    - General Electric Co.
    - Rawson Elec. Inst. Co.
  - **Indicating**
    - General Electric Co.
    - General Radio Co.
    - Rawson Elec. Instru. Co.
    - Weston Elec. Inst. Corp.
  - **Recording**
    - Bristol Company
    - Esterline-Angus Co.
    - General Electric Co.
  - **Thermionic Rectifier**
    - General Radio Co.
- **WATER METERS**
  - Bailey Meter Co.
  - Brown Instrument Co.
  - Foxboro Co.
  - Morey & Jones, Ltd.
- **WATTHOUR METERS**
  - General Electric Co.
- **WATTMETERS**
  - **Indicating**
    - General Electric Co.
    - Rawson Elec. Inst. Co.
    - Weston Elec. Inst. Corp.
  - **Recording**
    - Bristol Company
    - Esterline-Angus Co.
    - General Electric Co.
- **WAVEMETERS**
  - General Radio Co.
- **X-RAY SPECTROMETERS**
  - Gaertner Scientific Corp.

A New Principle in **A.C.**

Microammeters & Millivoltmeters

Without Amplification. Free from Wave form and Frequency Errors up to 20,000 cycles.

Reduced Energy Consumption. 50,000 ohms per Volt as Voltmeter. Simple to Operate. Write for information on Rawson-Greibach Meters.

RAWSON ELECTRICAL INSTRUMENT CO.
Incorporated 1918
CAMBRIDGE, MASS.
Branch Office: 91 Seventh Avenue, New York City
Mid-Western Representative: **Earl N. Webber**, Daily News Bldg., Chicago, Ill.

What Instrument Do You Want to Buy?

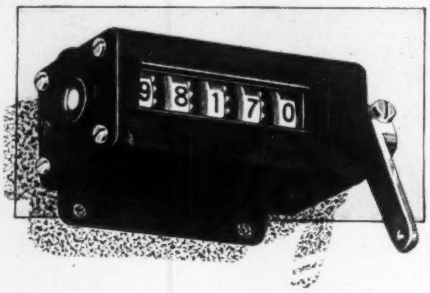
If you do not see listed in the Advertising pages or in the INSTRUMENTS INDEX the instruments and devices for measurement, inspection and control you wish to purchase . . .

the Publishers of this Journal

will be pleased to forward your request to the manufacturer of the instrument.

Veeder-ROOT

Small non-resetting *High-Speed* Counter

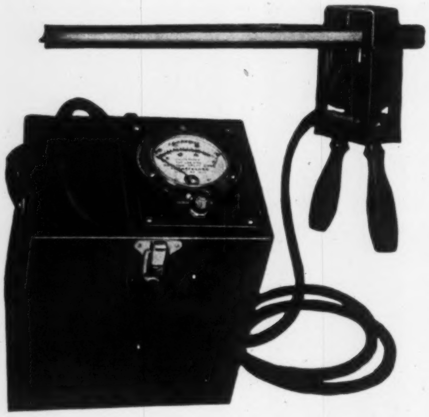


RECORDS operations, output, strokes or revolutions of any type of machine or mechanical device operating at *high speeds.* This Counter is especially designed to register accurately when run very fast; it can not over-register. . . Wheels are carried on a small bearing, contributing to a free-running, easily actuated movement. Standard types of driving mechanism are available: *Revolution, Direct Drive, Rotary Ratchet and Ratchet with Stops.* Regularly furnished with five figure-wheels; more may be had at slight additional cost. Illustration shows standard form for mounting, but the Counters are supplied where specified with flange-at-window for small extra charge.

BUILDERS of light, fast-running machinery or appliances have here a Counter wholly suitable and abundantly durable for *standard equipment* on their product. It gives your machine an added value and competitive advantage with the customer. Particularly in your new designs, the sales-appeal of Counter-equipment ranks with improvement-features in an up-to-date job. . . Our engineers will work with you on any problem of embodying this Counter in any type of machinery, standard or special, or in re-designing or adapting a Counter to any unusual application you may consider. Write us about any development that involves *automatic counting* or production-recording.

Veeder-ROOT INCORPORATED HARTFORD, CONN.

RUBICON
CURRENT TEST SET



A highly convenient instrument for measuring alternating currents without interrupting service. Described in Bulletin No. 180. Write for your copy.

RUBICON COMPANY
Electrical Instrument Makers
29 N. 6TH STREET PHILADELPHIA, PA.

ADVERTISERS' INDEX

B

Bailey Meter Company.................[illegible]
Baldwin-Southwark Corp. ....A[illegible]
Bristol Company ....Back Cover
Brown Instrument Company.................Inside Back Cover

E

Esterline-Angus Co. ....A[illegible]

F

Foxboro Company, Inc. ....A[illegible]

G

Gaertner Scientific Corp. ....A[illegible]
General Radio Company ....A[illegible]

H

Hellige, Inc. ....A[illegible]

J

Journal of Scientific Instruments.................68

M

Morey & Jones, Ltd.................54

R

Rawson Electrical Instrument Co.................A7
Review of Scientific Instruments.................68
Rubicon Company A8

T

Taylor Instrument Companies.................Inside Front Cover

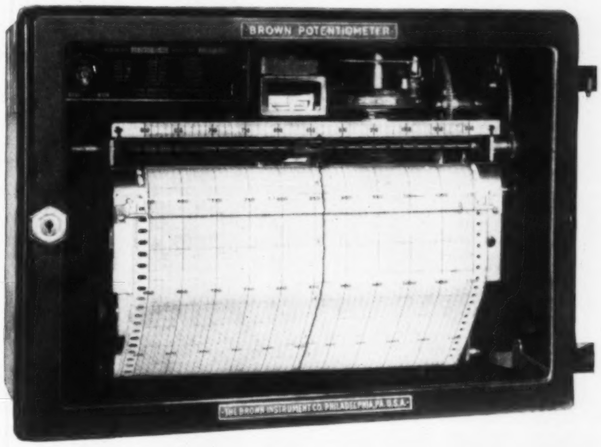
V

Veeder-Root, Inc. A8

W

Weston Electrical Instrument Corporation.................A[illegible]

*Accurate to 1/5 of 1%



The remarkable accuracy of Brown potentiometer recorders and controllers is due to the following:

1. 40" Helical slide wire with 1900 convolutions. Each slide wire is uniform within 1/10 of 1%.
2. Long 40" slide wire permits robust wire (.020" dia.) to be used as a winding, unaffected by wear after long service.
3. Because of the large diameter wire used on the slide wire each convolution can be selected accurately; each convolution is equivalent to only .006" (6/1000ths of 1") on the chart.
4. Oil immersion of slide wire—(A) eliminates wear resulting from the contact brush riding on the slide wire, (B) protects the slide wire from corrosion and dirt and thereby prevents high resistance contacts.
5. Positive drive mechanism with non-slip clutch eliminates lost motion and variation in response, due to wear. It takes its smallest step of 1/1200th of the chart space with absolute definiteness.
6. Secondary pointer system relieves galvanometer pointer of all strain and produces large mechanical movements for actuating the drive mechanism, eliminating the need for microscopic mechanical movements.
7. Humidity chart compensator corrects for changes in width of chart due to changes in humidity of surrounding air. Without this compensation, errors up to 1% (15° at 1500°) can occur with changes from 10 to 90% in atmospheric humidity.
8. Cold junction enclosed terminal equalizing block insures accurate cold junction compensation, eliminating unsuspected errors due to drafts and air currents, frequently present in instruments which do not have this feature.
9. Air cell with internal temperature compensator available instead of dry batteries. Standardizing of potentiometer only once a month—water renewal once every three months. Life—2½ years.

***Every Brown potentiometer recorder or controller of standard range is guaranteed accurate within 1/5 of 1% of the range, when it leaves our factory. If properly installed and maintained, it will retain this accuracy.**

If you want real accuracy in a potentiometer pyrometer, you require the Brown.

THE BROWN INSTRUMENT COMPANY
4482 Wayne Avenue Philadelphia, Pa.
Branches in 22 Principal Cities

BROWN POTENTIOMETER PYROMETER